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EVALUATING THE CLAIMS OF NETWORK CENTRIC WARFARE

by

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December 2005

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EVALUATING THE CLAIMS OF NETWORK CENTRIC WARFARE

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ABSTRACT

In response to technological advances, Network Centric Warfare (NCW) emerged as a theory to leverage the technology available in today’s world. Advocates of NCW claim that technology will improve information sharing by “…robustly networking a force”, thereby improving mission effectiveness. This study proposes a methodology with which to test the first tenet of NCW: a robustly networked force improves information sharing.

Lessons learned from Human Systems Integration (HSI) demonstrate that in order to improve mission effectiveness, characteristics of both the human and the technology must be considered. As such, the impact of human characteristics and traits on mission effectiveness, as measured by individual and team performance, are assessed using a computer simulation, C3Fire.

Results at the individual level suggest that persons scoring high on extraversion and low on pessimism perform better than those scoring low on extraversion and high on pessimism. In contrast, at the team level, homogenous teams as measured by optimism-pessimism perform worse than diverse teams. Results of this thesis provide a methodology with which to examine NCW’s claims in a laboratory setting. Preliminary evidence demonstrates the need to consider human characteristics and traits in the design and composition of network teams.

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EXECUTIVE SUMMARY

Societal progression from the Industrial to the Information Age has produced the need for transformation in warfighting. In response to technological advances, Network Centric Warfare (NCW) emerged as a theory to leverage the technology available in today's world. Specifically, advocates of NCW claim that technology will improve information sharing by "…robustly networking a force", thereby improving mission effectiveness. However, just as with any new theory, a methodology and procedure must be in place for validating its claims. This study addresses this gap by proposing a methodology with which to test the first tenet of NCW: a robustly networked force improves information sharing.

Lessons learned from Human Systems Integration (HSI) demonstrate that in order to improve mission effectiveness, characteristics of both the human and the technology must be considered. As such, the impact of human characteristics and traits (i.e., personality, cultural adaptability, and optimism-pessimism) on mission effectiveness, as measured by individual and team performance, are assessed using a computer simulation, C3Fire.

Results at the individual level suggest that participants scoring high on extraversion and low on pessimism perform better than those scoring low on extraversion and high on pessimism. In contrast, at the team level, homogenous teams as measured by optimism-pessimism, perform worse than diverse teams. Results of

this thesis provide a methodology in which to examine NCW’s claims in a laboratory setting. Findings from this study demonstrate the need to consider human characteristics and traits in the design and composition of network teams.

I. INTRODUCTION

A. PROBLEM STATEMENT

Fundamental changes in technology, weapon systems, and marketplace commodities functioning as tools of war are affecting the very character of warfare. In response to these changes, the United States Department of Defense (DoD) is transforming. This transformation encompasses how technology and new operational concepts and structures can be used to augment military preparedness (Garstka, 2003). In addition, this recent transformation of the DoD has embraced Network Centric Warfare (NCW) as an emerging theory of warfare (Cebrowski, 2002).

In theory, NCW accelerates the ability to respond to uncertainty in dynamic situations by relying on human networks. Advocates of NCW claim that adopting NCW will improve information exchange and sensemaking which are referred to as macrocognitive functions. In theory, effectiveness in macrocognitive functions increases because complex cognitive systems would enable people to coordinate more efficiently across time, space, and organizational boundaries. However, claims of the benefits of NCW have not been systematically verified in field or laboratory settings.

One approach to verifying improvements in information exchange and sensemaking is the study of macrocognition. Macrocognition describes mental activities that must be successfully accomplished to perform a task or achieve a goal (Klein et al., 2003). Macrocognition is a term used to indicate the level of description of the cognitive

functions that are performed in natural versus artificial laboratory settings (Cacciabue & Hollnagel, 1995). As part of macrocognitive functions, problem detection, uncertainty management, and situated cognition occurs. These processes are generally performed in collaboration by a team working in a natural setting.

In theory, NCW is one step towards military transformation. However, a methodology for assessing NCW's benefits in macrocognitive performance has not been established. In some cases, researchers have chosen to explain variability in performance through individual dispositions such as personality. Therefore, other factors such as individual characteristics and traits may also affect performance.

B. OBJECTIVES

The objective of this research effort is to design and establish a laboratory and research method focused on evaluating the claims of NCW from a human systems integration (HSI) perspective. The specific goals of this effort include:

- To develop and implement a laboratory for evaluating team performance.
- To design and test a set of procedures for applying individual and team performance measures.
- To evaluate the tenets and claims of NCW from a HSI perspective.
- To demonstrate the utility of the Dynamic Model of Situated Cognition (Miller & Shattuck, 2005) in providing a descriptive analysis in team effectiveness and its applicability in future research.

C. RESEARCH QUESTIONS

The specific research questions addressed in this study include:

- Are there individual characteristics and traits that relate to individual performance?
- Are there individual characteristics and traits that relate to overall team performance?
- Do diverse teams perform differently from homogenous teams?
- Are there performance differences when blocking on various team member traits in team design?

D. BACKGROUND

As cited in Office of Force Transformation (2005), former Secretary of Defense Paul Wolfowitz (2001) stated:

> Throughout history, warfare has assumed the characteristics of its age and the technology of its age. Today we see this trend continuing as we move from the Industrial Age warfare with its emphasis on mass to Information Age warfare, which highlights the power of networked distributed forces. p.7

The characteristics of a networked distributed force are particularly evident in coalition command and control (C2) operations. Coalition C2 staffs are expected to use networks to share information among diverse members. C2 staffs involve multinational team members characterized by divergent national interests. Differences in culture, organizational affiliation, and professional backgrounds are believed to affect macrocognitive functions and processes such as uncertainty management (Klein, Pongonis & Klein, 2000).

To capitalize on the perceived advantage of networked distributed teams, the U.S. military has adopted NCW as an emergent theory. However, with any new theory there is the challenge of demonstrating its utility and worth. If NCW is to be fully embraced, empirical and qualitative research must provide support for its claims.

Proponents of NCW would argue that NCW is required for effective military transformation. In theory, mission effectiveness is enhanced when information sharing occurs as a result of “robustly networking a force.” As part of networking a force, Alberts and Hayes (2003) emphasize interoperability, which is the ability to work together. However, our understanding of technology and its integration into military operations to enhance mission effectiveness is incomplete. A portion of this gap between leveraging technology to enhance mission effectiveness includes the dynamic interaction of team members and an understanding of how individual characteristics and traits contribute to team interaction.

Decades of team research have been conducted, but the findings do not provide the evidence needed to accept or refute NCW claims. Research at the macrocognitive level is needed to test NCW assumptions. Salas et al. (2003) reviewed twenty-five years of research on team effectiveness. They identified seven areas needing research. Two of these are: (1) the need to understand distributed teamwork, and (2) the need to focus on team culture.

E. HUMAN SYSTEMS INTEGRATION

In this thesis, we investigate the claims of NCW from an HSI perspective. HSI is a multidisciplinary field with eight basic areas or domains of study:

- Manpower
- Personnel
- Training
- Human Factors Engineering
- Health Hazard
- System Safety
- Personnel Survivability
- Habitability

We focus on three of these eight domains: personnel, training, and human factors engineering (HFE). Personnel and training include aspects of selection and classification; physical, cognitive, and educational characteristics; knowledge, skills, and abilities; and, finally, simulation and virtual environments. HFE is the integration of physical and mental limits, biases, and behaviors into system definition, design, development, and evaluation to optimize human-machine performance (Lockett & Powers, 2003). The personnel, training, and HFE domains of HSI provide a foundation by which claims of NCW can be tested.

F. THESIS ORGANIZATION

In the next chapter, NCW theory and literature pertaining to factors that influence macrocognitive functions are described. Since a methodology for testing NCW's claims has not been previously created, Chapter III provides detail regarding hardware/software use in the laboratory setting. This is followed by a description of the pilot study in Chapter IV. Finally, Chapters V and VI present the results, conclusions, and recommendations from the study.

II. LITERATURE REVIEW

The literature review is divided into multiple sections. The first section addresses the theory and claims of NCW. Other sections focus on personality, cultural adaptability, and optimism-pessimism. Finally, a conceptual model is described to demonstrate how personality, cultural adaptability, and optimism-pessimism influence how teams perform.

A. NETWORK-CENTRIC WARFARE

NCW has become synonymous with recent attempts by the DoD and other military forces to leverage the networking capabilities of the information age. Cebrowski and Garstka (1998), in one of the earliest references to NCW, state that “...NCW derives its power from the strong networking of a geographically dispersed force.” NCW is about human behavior within a network environment. The word “network” (i.e., as a noun) refers to the information technology and can only be an enabler. Used as a verb, “to network” implies human behavior, the action and the main focus of NCW (Office of Force Transformation, 2005).

Descriptions of NCW concepts are found in *Power to the Edge* (Alberts & Hayes, 2003). Stemming from the work of others, they list four tenets that describe the U.S. military’s approach to NCW:

- A robustly networked force improves information sharing.
- Information sharing and collaboration enhances the quality of information and shared situational awareness.

- Shared situational awareness enables collaboration and self-synchronization and enhances sustainability and speed of command.
- These in turn dramatically increase mission effectiveness.

These tenets facilitate the U.S. military's implementation of NCW across four domains: physical, information, cognitive, and social. The physical domain encompasses operations such as strike, protect, and maneuver. The information domain includes activities of information sharing, creation, and manipulation. The cognitive domain embodies perceptions, awareness, beliefs, and values. Finally, the social domain recognizes interactions between and among organizational elements. Miller and Shattuck (2005) refer to a fifth domain, the ecological domain. The ecological domain has been recently proposed by Lindh (2004) to address the domain of context.

As Figure 1 illustrates, the domains of warfare conceptualized in U.S. military doctrine overlap with one another. An analysis of each domain of warfare is beyond the scope of this research. However, the interaction of the social and cognitive domains (later referred to as socio-cognitive) comprise information exchange and sensemaking (Alberts & Hayes, 2003), the main focus of this research.

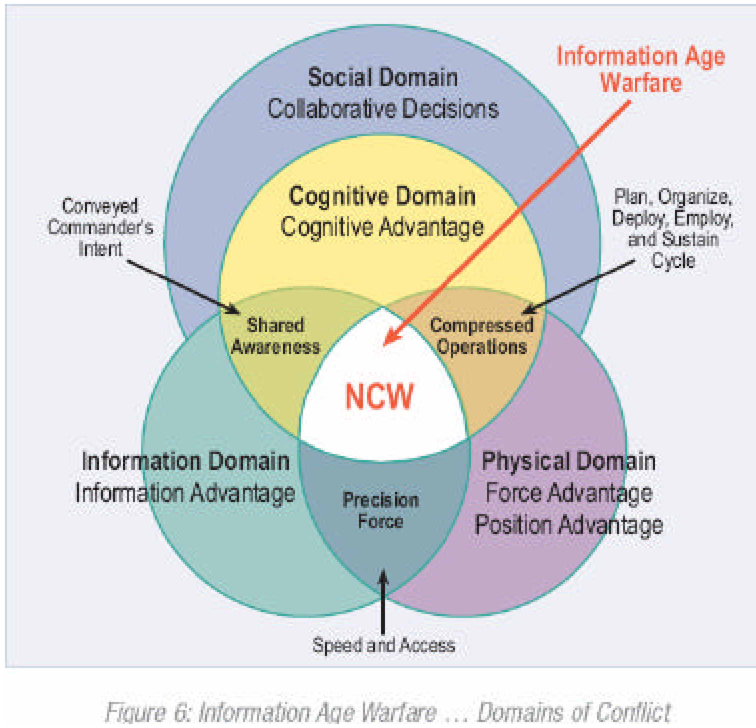

Figure 1. Domains of Warfare Overlapping (From: Office of Force Transformation, 2005, p. 21)

The socio-cognitive domain comprises macrocognitive behaviors such as information exchange and sensemaking (Figure 2, NCW Conceptual Framework). The NCW Conceptual Framework is the result of a 2002 workshop on NCW and networked enabled capabilities (Evidenced Based Research, 2003). This framework emphasizes behaviors which are believed to be critical in macrocognition. Behaviors such as sensemaking are addressed at the individual and team level (Alberts, Hayes, & Signori, 2001).

At the team level, macrocognitive behaviors include the degree to which (1) information is shared and (2) shared awareness is achieved. Proponents of NCW believe that information and networking "...form the center of Network Centric Operations" (Evidenced Based Research, 2003, p. 32). The extent to which teams are networked (the

quality of networking) along with their ability to rapidly share information (the quality and degree of information sharing) are said to be critical in determining overall effectiveness. Sensemaking involves activities that allow individuals to “make sense” of information in the context of experience, use this information to make inferences, and organize information into decisions (Evidenced Based Research, 2003). Alberts and Hayes (2003) state “...these variables are at the heart of the collaborative processes that NCW seeks to exploit” (p. 99).

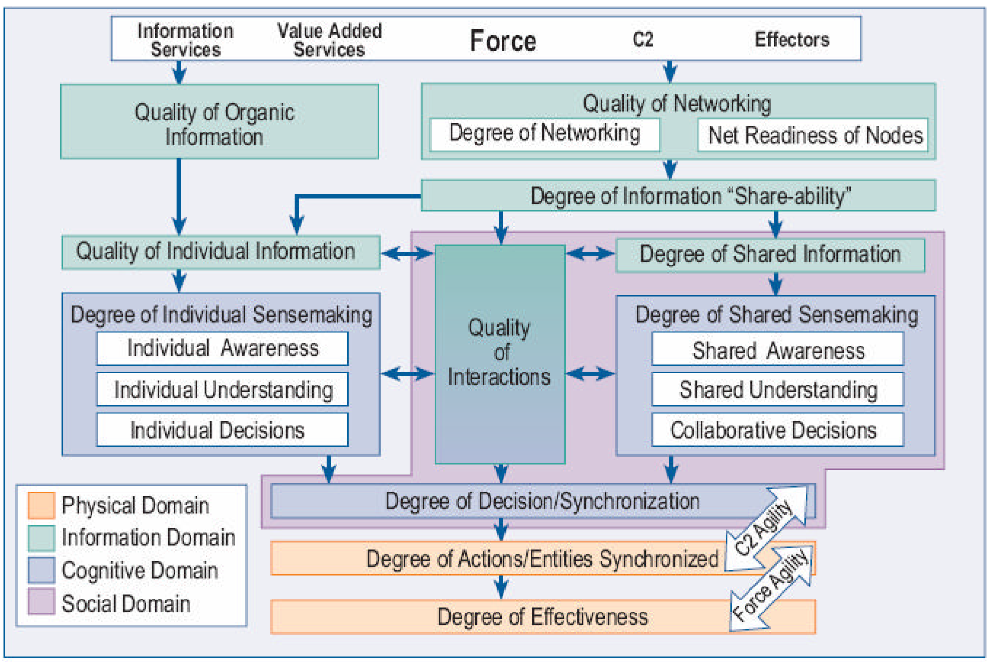

Figure 11: Top-Level NCO Conceptual Framework, Version 1.0

Figure 2. NCW Conceptual Framework (From: EBR, 2003, p. 4)

B. PERSONALITY

The study of personality in characterizing team effectiveness or understanding military adversaries dates back to World War II. During this time, personalities of enemy nations including Germany, the Soviet Union, and

Japan were studied by anthropologists at the direction of the U.S. government (Hofstede & McCrae, 2004). Trait psychology emerged as a contemporary approach to the study of personality. Trait psychology focuses on the assessment of individual differences in enduring dispositions as predictors of behavior. Dispositions such as personality are one method by which researchers have chosen to explain variability in team performance.

Central to the study of trait psychology and the characterization of personality is the development of the Five-Factor Model (Digman, 1990). The Five-Factor Model emerged as a result of over 70 years of systematic research beginning with efforts to organize the language of personality (John et al., 1988; Digman, 1990). Klages (1926) suggested that a careful analysis of language would assist in the understanding of personality which lead to Baumgarten’s (1933) examination of personality terms commonly found in the German language (as cited in Digman, 1990).

There have been other taxonomies of personality encompassing as few as three factors – Psychoticism, Neuroticism, and Extroversion/Introversion (Eysenck, 1960) and as many as 16 factors (i.e., Cattell’s Sixteen Personality Factor System; Cattell, 1965). As cited in Digman (1990), the work of Fisk (1949) and Tupes and Christal (1961) helped to establish the superiority of a five-factor approach. Replicated by later researchers (for a review see Digman, 1990), the Five-Factor Model has been recognized for its robustness. Any model for structuring

individual differences will have to encompass the Big Five dimensions at some level (Digman, 1990).

The Five-Factor Model consists of five dimensions of personality (Digman, 1990), often referred to as the Big Five. Personality researchers have failed to reach a consensus on the names representing each dimension. For this thesis, Costa and McCrae’s (1985) five personality constructs are used. The five constructs are known as extraversion, agreeableness, conscientiousness, neuroticism, and openness. Within each dimension, each construct is defined by at least six specific traits or facets which are addressed in further detail later in this section.

Research within the last few years has provided support to the utility of using personality measures as predictors of performance. McHenry et al., 1990 (as cited in Neuman & Wright, 1999) observed that personality is a predictor of job performance beyond general cognitive ability and job-specific skills for Army personnel. The following sections are intended to provide a more detailed explanation of each of the Big Five and its implications for assessing individual and team performance.

The Big Five factor of **Conscientiousness** is comprised of competency, dutifulness, need for achievement, self-discipline, and the tendency to think carefully before acting (Barrick & Mount, 1991). According to Barrick and Mount (1993), conscientiousness is related to individual performance regardless of task requirements. Later research (Kichuck & Wiesner, 1997; Neuman & Wright, 1999) suggested a relationship between conscientiousness and team

performance. Teams, whose members score high on the “need for achievement”, one facet of conscientiousness, outperform teams whose members scored low (see French, 1958; Schneider & Delaney, 1972; Zander & Forward, 1968).

Agreeableness is characterized by trust, straightforwardness, altruism, compliance, modesty, and the ability to be tender-minded (Barrick & Mount, 1991). In their review, Neuman and Wright (1999) suggest that agreeableness is a predictor of job performance at the individual level (see Rose et al., 1994; Tett, Jackson, & Rothstein, 1991). At this level, facets of agreeableness such as trust, straightforwardness, altruism, and compliance are traits that are desirable for the social interactions found among team members (Aronoff & Wilson, 1985). Teams characterized by agreeable members are expected to exhibit interpersonal skills such as ability to resolve conflict and communicate openly in a manner which promotes information exchange and sensemaking (Aronoff & Wilson, 1985; Neuman & Wright, 1999; Agarwal, 2003). In their analysis of the human dimension of NCW, Warne et al. (2004) cite research which demonstrated that the extent to which an individual trusts another significantly impacts their willingness to share valuable information with others (see Fine & Holyfield, 1996).

Extraversion is characterized by sociability, gregariousness, assertiveness, talkativeness, and activeness (Barrick & Mount, 1991). Kickuk and Wiesner (1997) cite research showing that extroversion is positively related to team performance (Haythorn, 1953; Ghiselli & Lodahl, 1958; Smelser, 1961; Altman & Haythorn,

1967; Bouchard, 1969; Shaw & Harkey, 1976; Driskell et al., 1987; Williams & Sternberg, 1988) and participation with the team (Mann, 1959; Watson, 1971). Extroverts are said to help facilitate intra-team communication and are generally ready to share information (Bradley & Herbert, 1997).

Neuroticism is characterized by traits such as anxiety, depression, anger, embarrassment, emotionality, and insecurity (Barrick & Mount, 1991). Neuroticism has also been thought of as a lack of emotional stability or adjustment (Digman, 1990). Neuroticism has not been found to be related to performance (Kickuk & Wiesner, 1997). However, after reviewing studies completed by Haythorn, (1953), Man (1959), Shaw (1971) and Thomas et al. (1996), they posit that Neuroticism may be negatively correlated with team performance.

Traits associated with **Openness** include imagination, culture, curiosity, originality, broad-mindedness, intelligence, and having an artistic ability (Barrick & Mount, 1991). In a review by Kichuk and Wiesner (1997), openness to experience is said to be predictive of an individual’s training proficiency but not predictive of his/her performance. The relationship between openness and overall performance is inconclusive (Kichuk & Wiesner, 1997).

C. CULTURAL ADAPTABILITY

Culture has often been used to explain human behavior, but “…there is no single, accepted definition” (Bird, 2001,

p.2). However, there are characteristics which help conceptualize culture. Bird (2001) identifies four common characteristics:

> 1. Culture includes systems of values;
> 2. Culture is learned, not innate;
> 3. Culture distinguishes one group from another; and
> 4. Culture influences beliefs, attitudes, perception and behavior in ‘somewhat’ uniform and predictable ways. (pp. 2-3)

In the context of NCW, the study of culture may be best viewed as a lens (Trandis, 1994). The ability to examine culture through a lens provides the flexibility to study culture at both an individual and team level. This approach also allows researchers to examine the dynamic relationships that may exist between the four previously mentioned characteristics of culture.

Cultural differences affect coordination and communication, which are factors of sense-making. In their review of culture and team performance, Powell, Piccoli, and Ives (2004) suggest that differences in culture may lead to coordination difficulties (see Johansson et al., 1999; Kayworth & Leidner, 2000; Maznevski & Chdoba, 2001; Robey et al., 2000) and create obstacles to effective communication (see Kayworth & Leidner, 2000; Sarker & Sahay, 2002; van Ryssen & Godar, 2000).

Cultural differences within teams may also be magnified in network-centric environments. Networking implies linking individuals together to work in teams. Thus, networking, from a human sense, ultimately results in teamwork. Teamwork connotes individual accountability, information exchange, and a general sense of working

together (Drucker, 1999). Consequently, teamwork is viewed as a skill and its absence can be a barrier to effective performance (Warne et al., 2004).

Klein, Pongonis, and Klein (2000) identify five cultural differences that can disrupt sensemaking, decision-making, coordination, and communication in military team work: (1) power distance, (2) dialectical reasoning, (3) counterfactual thinking, (4) risk assessment and uncertainty management, and (5) activity orientation. This research focuses on only one of these five differences, uncertainty management.

Uncertainty is “the state of being unsettled or in doubt” (American Heritage Dictionary, 2000). Uncertainty can be a function of ambiguous information, perceived threat, or harmful situation. Greco and Roger (2001) advocate that “...stress under these conditions varies as a function of an individual’s efforts of, appraisal of, and coping with, the event” (p. 517). The study of uncertainty and human behavior has become known variously as tolerance of ambiguity, uncertainty avoidance, anxiety, and risk avoidance. These terms are used interchangeably in this thesis.

Uncertainty has been conceptualized and studied within a variety of cultural contexts. At the national culture level, uncertainty may be termed uncertainty avoidance. Cultures classified as strong in uncertainty avoidance are active, aggressive, emotional, compulsive, security-seeking, and intolerant. Other cultures that can be characterized as low in uncertainty avoidance are contemplative, less aggressive, unemotional, relaxed,

accepting personal risks, and relatively tolerant (Hofstede, 1991). Uncertainty avoidance has also been "related to anxiety, need for security and dependence upon experts" (Hofstede, 1980, p.110).

The need for certainty is not only different between cultures, but also within cultures. As a trait, the need for certainty has been labeled as an intolerance of ambiguity. Intolerance of ambiguity has been defined as "the tendency to perceive (i.e., interpret) ambiguous situations as sources of threat" (Budner, 1962, p. 29). Ambiguous situations perceived as threats include new technology, dynamic and complex environments, asymmetry of the battlefield, and dynamic information exchange networks. Overall, a high need for certainty or a low tolerance for ambiguity, imply "a preference for familiarity, symmetry, definiteness, and regularity" (Bar-Tal, 1994, p. 45).

Stress is one of the human responses to uncertainty. Stress can be initiated by a distinct event, ambiguous and incomplete information, or a perceived threat. Stress also has an effect on performance. Performance differences which may result from stress include premature reactions, restricted use of relevant cues, more errors on cognitive tasks, and increased use of schematic or stereotyped judgments (see Bar-Tal, Raviv, & Spitzer, 1999). However, not everyone's reactions to stressors are the same.

A 12-month team performance study led by Sutton and Pierce (2003), found that uncertainty affected situation assessment (i.e., information exchange), coordination (i.e., response sequencing), and general support behavior (i.e., activity monitoring). Their study assessed the

degree to which cultural cognitive dimensions impact teamwork in a multinational headquarters. Specifically, teams comprised of individuals scoring high on need for certainty (uncertainty avoidance) engaged in behaviors that were different from team members with a low need for certainty. Individuals scoring high on need for certainty produced much more detailed information in the situation assessment phase of planning and coordination. These individuals also developed well-defined processes for information exchange and coordination.

D. OPTIMISM AND PESSIMISM

Pessimism is defined as a general tendency to have negative expectations. "Optimism is a disposition inclining one to positive expectations; pessimism inclines one to negative expectations" (Helton et al., 1999, p. 311). Optimists and pessimists respond to stress in different ways. Stress narrows attention and causes important information to be overlooked. This narrowing affects the problem solving process, another process related to macrocognition (Hoffman, Roesler, & Moon, 2004). Central to the activity of problem solving is sensemaking (Russell et al., 1993). Seligman (as cited in Grasha, 2000) suggests that optimists are willing to challenge problems, persist until a solution is found, and involve others in resolving issues (Seligman, 1991). Optimists are believed to participate more in information exchange.

E. MODEL OF DYNAMIC SITUATED COGNITION

NCW advocates cite the need for a process model to assess NCW's claims. However, such a process model has not

been available until recently. Miller and Shattuck (2005) proposed filling this gap using their Dynamic Model of Situated Cognition (DMSC) (Figure 3).

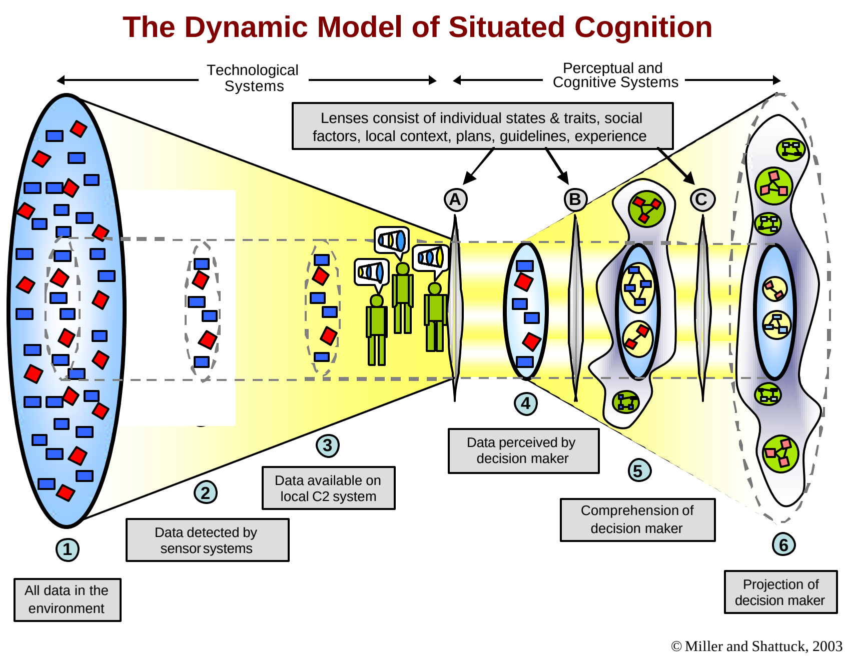

Figure 3. The Dynamic Model of Situated Cognition (From: Miller & Shattuck, 2004)

The DMSC emerged as an attempt to illustrate the relationships between technological systems and human perception and cognition. Since its creation, the DMSC has been used to describe what happens in operational environments with people who are engaged in goal directed behavior (see Miller & Shattuck, 2004, 2005). It has also been adapted by Miller and Shattuck (2005) as a process model for NCW (Figure 4). The DMSC can be used to examine macrocognitive processes and functions of information exchange and sensemaking which reside in the socio-cognitive domain. Situated cognition describes the fact that macrocognitive functions are generally performed in collaboration by a team working in a natural setting.

Accordingly, the left side of the model receives the greatest attention in this research.

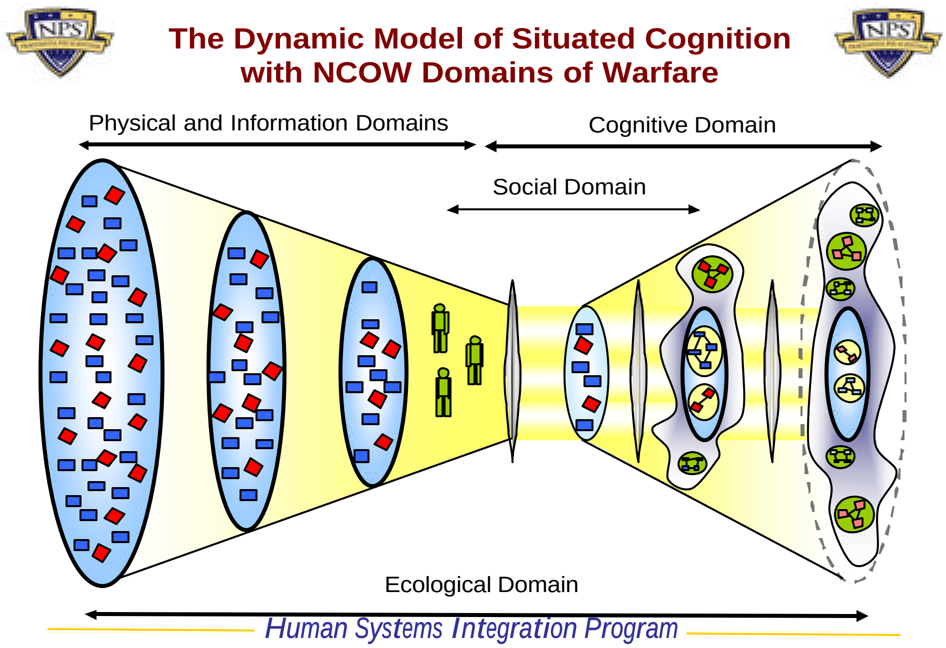

Figure 4. The DMSC adapted to the NCOW Domains of Warfare (From: Miller & Shattuck, 2005)

The DMSC consists of a series of lens (A, B, and C, see Figure 3). Lens A, the lens between Ovals 3 and 4, directs attention to selected incoming stimuli. These stimuli are, in most cases either visual or auditory. Between Ovals 4 and 5 is Lens B. Lens B is believed to influence how data are organized into information. The lens between Ovals 5 and 6, Lens C is believed to guide the process of extrapolating current information (Shattuck & Miller, 2005).

Miller and Shattuck (2005) state that there are at least six classes of information embedded in the lenses that influence macrocognitive processes. The six classes of information are: 1) individual states and traits, 2)

social factors, 3) local context, 4) plan, 5) guidelines, and 6) experience. Two are applicable in the context of this research: individual states and traits, and social factors. Individual states and traits represent relatively enduring (e.g., personality) and transient (e.g., fatigue) characteristics of an individual. For a more detailed discussion of human trait and state measurements, see Miller et al. (2003). Social factors include issues ranging from team dynamics (e.g., homogeneity) to cultural differences. Together these two factors may significantly influence what is perceived by team members (Oval 4).

The ovals to the right of lens A (Oval 4, 5, and 6) represent perception, comprehension, and predictions – loosely referred to as macrocognitive processes. Perception (a process occurring in Oval 4) is achieved through active and passive processes such as information exchange. Active processes refer to data requested or "pulled" by team members. Passive processes refer to data provided or "pushed" to team members. Comprehension is represented in Oval 5. Comprehension is a cognitive process described by terms such as fusion, integration, analysis, explanation, interpretation, and pattern recognition (Endsley, 1995). Comprehension is loosely referred to as sensemaking. Dervin's theory of sensemaking, (as cited in Salvolainen, 1993) is defined as: "… behavior, both internal (i.e., cognitive) and external (i.e. procedural), which allows the individual to construct and design their movement through time-space" (p.16). Finally, Oval 6 represents projections of individual team members. These projections are based on what have been comprehended (Oval 5), and the affect of an individual's lens (Lens C). These

same lens components (i.e., individual states and traits and social factors) are believed to influence macrocognitive processes such as information exchange and sense-making.

NCW, by its very nature, involves multiple actors, both human and machine. Miller and Shattuck (2005) state "As we move from an individual to the network of individuals that characterize NCW" the technological (or physical and information domains) remain the same. Figure 5 below illustrates how ground truth (Oval 1) and data detected by sensor systems (Oval 2) will remain the same for each individual. However, Oval 3 through Oval 6 will differ for each of the three individual team members. As an illustration, the lines from individuals A and C to individual B represent the way individuals A and C convey information to individual B. The same descriptions of lenses and ovals are applicable in this illustration.

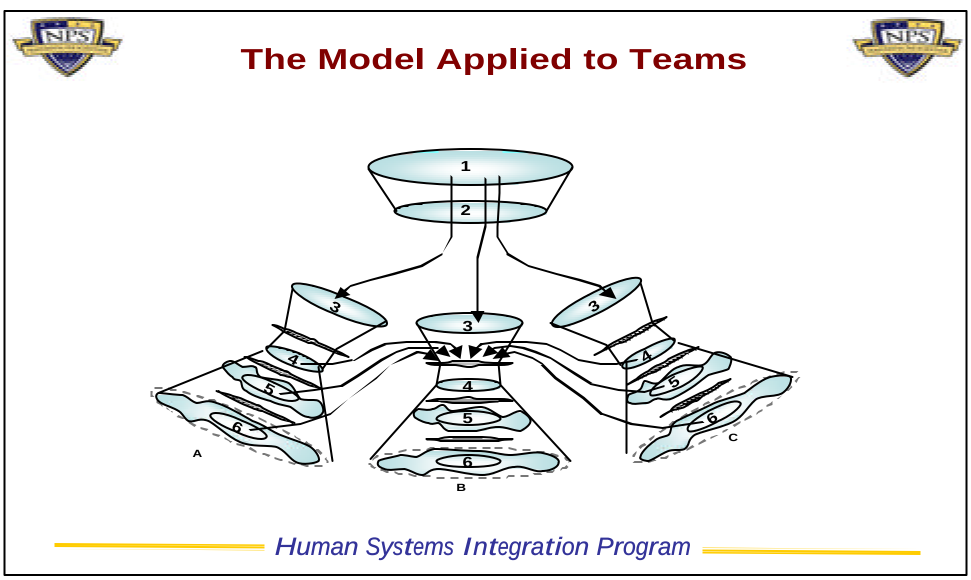

Figure 5. DMSC Applied to Teams (From: Miller & Shattuck, 2005, Published in Conference Proceedings

Situated cognition is a dynamic, ongoing process (Clancey, 1997). Figure 6 further represents this ongoing process by its emphasis on feedback in situated cognition. The feedback loops shown in Figure 6 provide insight into macrocognitive processes of networked individuals. The feedback loops flow from Oval 5 (comprehension) to Ovals 1, 2, 3, 4 (environmental, sensors, C2 workstation, and perception). Feedback loops from Oval 6 (projection) also flow to Ovals 1, 2, 3, 4, and 5. Additional feedback loops exists in the model as well. These feedback loops extend from Oval 5 (comprehension) to the lenses and from Oval 6 (projection) to the lenses. Miller and Shattuck (2005) have postulated that the lenses are dynamic and constantly change.

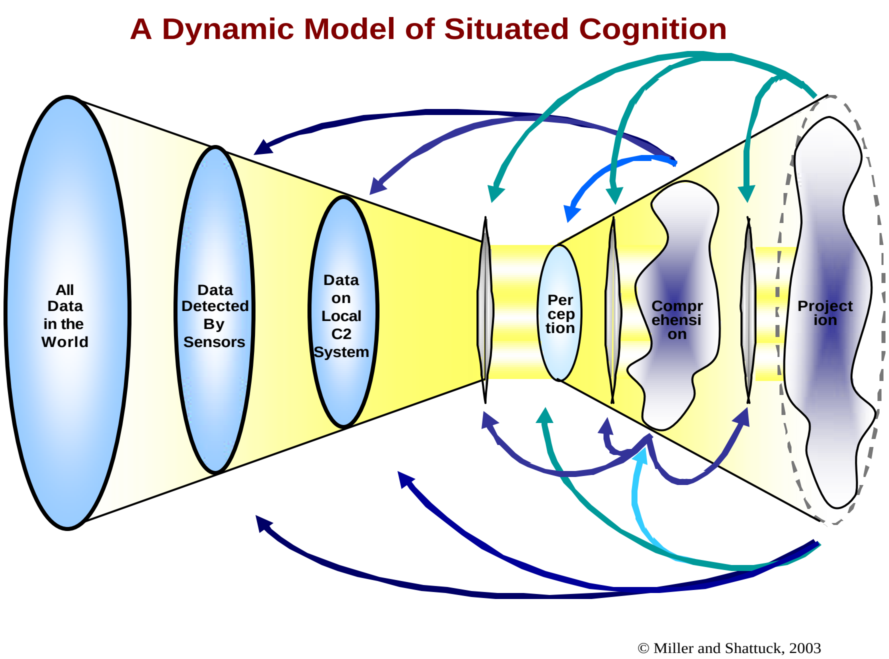

Figure 6. DMSC Feedback Loops, (From: Miller & Shattuck, 2004, p.5)

The factors influencing effective macrocognitive processes must be investigated insofar as they underpin mission effectiveness (Warne et al., 2005).

III. DESIGN AND IMPLEMENTATION OF THE TEAM PERFORMANCE LABORATORY

A. BACKGROUND

Much of the time involved in this thesis effort was spent designing, constructing, and configuring the Team Performance Laboratory. The Team Performance Laboratory uses computer software to assess and evaluate human factors considerations in team performance. The Human Systems Integration Laboratory (HSIL) was reconfigured to accommodate two semi-private four person laboratories. Additionally, four mobile desktop stations were configured for easy set-up and take-down given limited laboratory space. A two person observer station was set up to network, control, observe, and collect data on the eight Pentium 4 desktop computers used by team members in the C3Fire simulation.

B. SOFTWARE

Testing the claims of NCW using a computer generated synthetic environment required reviewing numerous game-based software packages. These included Mission to Mars, AWACS-AEDGE, Never Winter Nights – SABRE, and C3Fire.

Mission to Mars is a computer-generated interactive simulation currently being used by researchers to evaluate distributed interactive communication between dispersed elements. The simulations are developed around resource and time management themes within the context of geologic exploration expeditions on the surface of Mars. Groups of three-person crews are expected to operate a simulated exploration vehicle, an “Orbiter”, “Lander”, or “Rover”,

via an individual workstation. The task is designed to last up to four hours. Mission to Mars automatically records both crew performance and psychosocial communication interactions (Hienz et al., in press).

The Airborne Warning and Control System – Agent Enabled Decision Guide Environment (AWACS-AEDGE), developed using 21st Century Systems Inc.'s AEDGE™ infrastructure is a distributed, real-time team decision support environment. It is comprised of simulators, intelligent agents and user interfaces (Barnes, Petrov, & Elliott, 2002). The AWACS-AEDGE was developed to represent core characteristics of the Airborne Warning and Control Systems (AWACS) Weapons Director (WD) team. Core characteristics of the AWACS-WD team include providing airborne surveillance, control, and communications functions for tactical and air defense forces. The AWACS-AEDGE was developed as an agent-based C2 team decision support platform for research and training (Petrov et al., 2002).

SABRE (Situation Authorable Behavior Research Environment) is a joint Defense Modeling and Simulation Office and Air Force Research Laboratory project. Developed by BBN Technologies, SABRE is a tool intended for team behavior research. SABRE is marketed as an aid for investigating general aspects of teamwork such as group decision-making, resource management, and information sharing. In addition, context-specific behaviors such as negotiating and accommodating mission-irrelevant requests for assistance are explored. This test-bed has been developed primarily to study the effects of personality and culture on behavior and performance in a cooperative team

mission (Leung, Diller, & Ferguson, 2005). Training time prior to data collection is approximately 2.5 hours (Warren et al., 2005).

The C3Fire microworld is a command, control, and communications firefighting simulation. C3Fire has been used for training and experimentation of team decision-making and team situational awareness (Granlund et al., 2001; Granlund, 2002). C3Fire generates a task environment in which a team of four people cooperate to extinguish a fire (see Figure 7). The user interface consists of several basic elements: a geographic information system (GIS), a diary, and an e-mail system. In the center of the user interface is a map consisting of a 40 x 40 matrix of cells; a map legend, clock, e-mail tool, and a truck status panel. Using these features, players of C3Fire control three types of trucks (firefighting, fuel, and water) and are responsible for working together via e-mail to extinguish the fire. Players need to maintain a picture of fuel and water states during the game. The game records a variety of performance data in the form of logs. Training time is approximately 2 minutes.

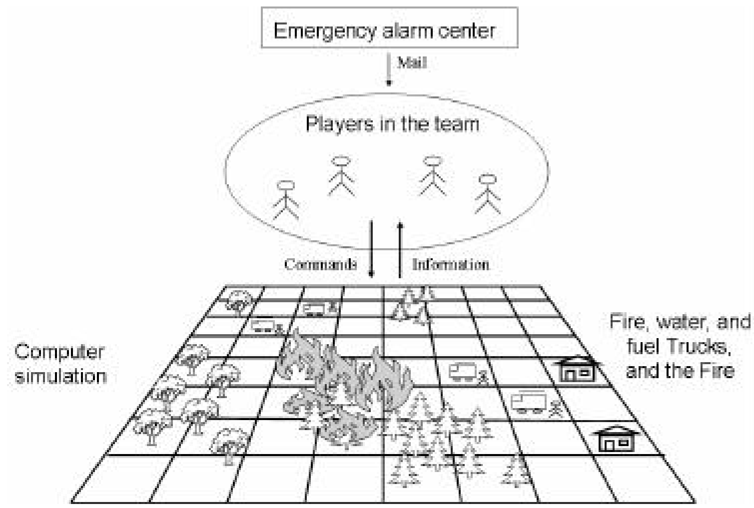

Figure 7. An example of C3Fire Microworld Setting, (From C3Fire Instructions Granlund, 2005, p. 1)

After reviewing the concepts of NCW and given the short amount of training time, C3Fire was chosen. C3Fire was also selected because it had been previously used to test concepts of NCW (Johansson et al., 2003).

C. INSTALLATION

C3Fire was installed on ten desktop Pentium 4 machines. In addition to the software, basic requirements for the team performance lab included:

- Two adjacent areas (Team Performance Laboratory) measuring at least 14’ X 14’. Each area should be fully isolated from other areas in the HSIL to protect against background noise. Each area may require as many as twelve surge-protected electrical outlets.
- Three 10/100 Ethernet ports capable of networking four computers at once.
- Ten Pentium 4 or 3 CPU with near 3.20GHz, 1.00 GB of RAM.
- Ten standard “qwerty” keyboards and two button mouse. Ten monitors of the same size are needed. Monitors should be no smaller than a 17-inch

Diagonal and 16-inch V.I.S., CRT, 1024x768 Pixels. Ideally, 19” or 20” Flat Panel LCD Monitors are required for resolution and interface visibility.

- All machines need to be configured by the Information Technology Assistance Center (ITACS) to receive a constant IP Address and connect to the NPS Intranet.

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IV. PILOT STUDY

Identifying and measuring human performance both on an individual and team level is challenging. Team performance variables must be operationally defined, using the constructs identified for specific operations or procedures and the resultant measurements selected for this study. Key variables selected for this study and their operational definitions are provided below. A major benefit of C3Fire and a deciding factor for its use in this study is its capability to automatically collect several kinds of performance data. The primary variable of interest in this thesis, information exchange (or information currency), is an indicator of overall NCW performance which has been previously identified in the literature. In the context of NCW, information exchange (information currency) is consistent with objective measures of information sharing and sensemaking at the team and individual levels. For more information on NCW variables in addition to the ones which have been identified below, see Appendix B. For C3Fire capabilities, refer to www.C3Fire.org.

A. VARAIABLES

1. Dependent Variables

a. Information exchange (information currency): communication lag time (in seconds) between sending and the receiver opening a message.

b. Overall C3Fire Performance – the number of cells in the 40 x 40 matrix of cells lost due to ineffective firefighting in a 17 minute session.

2. Independent Variables

a. Personality scores on each of five dimensions – measured using the NEO-FFI.

b. Uncertainty Management scores on each of three scales: (1) Uncertainty Response Scale, (2) Need for Cognitive Structure, and (3) Ability to Achieve Cognitive Structure

c. Optimism-Pessimism – total score from the OPI.

d. Conflict Avoidance – total score from the Conflict Avoidance questionnaire.

B. PARTICIPANTS

Much of the previous research on teams has used undergraduate students from civilian institutions, thereby threatening generalizability of the studies for U.S. military forces. Therefore, the current study specifically sought participants from a population of military officers expected to perform in network-centric operations.

Thirty-two NPS students and faculty members (average age = 34.1, standard deviation = 6.12) were assigned to eight teams who participated in the first phase of the exercise. Sixteen additional participants (both NPS students and faculty) participated but data from these latter participants are not included in this pilot study due to incomplete survey responses.

The pilot study focused on the performance of eight teams. Of the eight teams, five were all male. Two teams were of mixed gender and one team was all female.

Individuals in each team were known to each other. Naval Postgraduate School students enter as cohorts taking the same classes for 18 to 28 months, making it virtually impossible to avoid teams consisting of individuals who had

no prior experiences of working together. Consequently, each team was self-selected and entered the laboratory as a unit.

The 32 participants represented most branches of service including civilians from the DoD. See Table 1 for more detailed demographic data.

Navy	Army	Marines	Air Force	Coast Guard	DoD Civilian	Total
16	6	1	3	0	6	32

Table 1. Military Service Representation

C. INSTRUMENTS

A variety of standardized surveys were used for collecting individual characteristics and trait data. The surveys selected for this research were a mix of open- and closed-ended questions that were 3-5 pages in length. For consistency and ease of scoring, many of the surveys were scored using a five-point Likert scale (1 = Strongly Agree to 5 = Strongly Disagree).

The surveys listed below were selected because of their perceived ability to be related to team performance. The number of surveys selected was indicative of the absence of well defined individual characteristics and traits that are related to team performance literature (See Chapter II: Literature Review). Refer to the references listed for additional information on and a copy of each survey.

1. Demographic Questionnaire

The demographics questionnaire is a 15-item questionnaire with both open-ended and forced-choiced questions which assesses the participants’ (1) personal,

academic, and work-related background, (2) international experiences, (3) experience in the military and teamwork, and (4) experience with computers, especially chat programs. The 15-item questionnaire was adapted from ongoing research on Bridging Cultural Barriers to Collaborative Decision Making in Onsite Operations Coordination Centers (K. Smith, personal communication, August 22, 2005, 11:32PM).

2. NEO Five-Factor Inventory (NEO-FFI)

Team member personality was measured using the NEO-FFI, a 60-item questionnaire. It is the shortened version of the Revised NEO-Personality Inventory (NEO-PI-R; Costa and McCrae, 1992). The NEO-FFI provides an accurate and concise measure of the “Big Five” domains of adult personality: extroversion, agreeableness, conscientiousness, emotional stability, and intellect (or openness) and their facets (Briggs, 1989).

The NEO-FFI has adequate internal consistency, construct, and discriminative validity across diverse samples (Ball et. al., 2001; Costa & McCrae, 1992). The NEO-FFI Form S correlates with the NEO-PI-R domain scales at .77-.92 and has a internal consistency values ranging from .68-.86 (PAR, Inc., Retrieved 2005). Additionally, the NEO-FFI was chosen over other popular indices of personality because of its relational value to national cultural constructs previously mentioned in the literature (Hofstede & McCrae, 2004) and its 10-15 minute administration time.

3. Uncertainty Response Scale

The Uncertainty Response Scale (URS; Greco & Roger, 2001) is a 48-item scale which predicts individual differences in coping with uncertainty. The URS is comprised of three factors, Emotional Uncertainty (EU), Desire for Change (DFC), and Cognitive Uncertainty (CU). EU is the desire to which an individual responds to uncertainty with anxiety and sadness. DFC is the degree to which an individual enjoys novelty, uncertainty, and change. CU is the degree to which an individual prefers order, planning, and structure in an uncertain environment. Participants rate the degree to which a statement is true for themselves using a 5-point scale with endpoints being 1 = Never and 5 = Always. Scores for subscales are determined by totaling the point value of statements associated with each subscale. Higher scores indicate a greater tendency toward maladaptive responses to uncertainty (EU), greater enjoyment of the unknown (DFC), and greater preference for control under uncertain conditions (CU). The URS has an internal consistency of .89, .90, and .85 for subscales EU, DFC, and CU respectively, and test-retest reliability estimates of .79, .86, and .80.

4. The Need for Cognitive Structure Scale

The Need for Cognitive Structure Scale (NCS; Bar-Tal, 1994) is a 20-item scale that assesses the extent to which an individual prefers using cognitive structuring to achieve certainty. Cognitive structuring (or categorization) helps create certainty by filtering out inconsistent or irrelevant information. Participants rate

the degree to which they disagree or agree with statements using a 5-point Likert scale with endpoints of 1 = Strongly Disagree and 5 = Strongly Agree. Responses are totaled to create an “overall need for cognitive structure” score. Higher scores indicate a greater need for cognitive structure. The NCS has an internal consistency of .82 and test-retest reliability of .85 (Bar-Tal, 1993, 1994).

5. The Ability to Achieve Cognitive Structure Scale

There are individual differences in the ability to effectively organize information to fit existing knowledge structures or to process information that is inconsistent with existing structures. The Ability to Achieve Cognitive Structure Scale (AACS; Bar-Tal, 1994) is a 24-item scale that assesses this trait.

Participants rate the degree to which they disagree or agree with statements using a 5-point Likert scale with endpoints of 1 = Strongly Disagree and 5 = Strongly Agree. Responses are totaled to create an overall ability to achieve cognitive structure score. Higher scores indicate a greater ability to apply information processes that are consistent with an individual’s level of NCS. The AACS has an internal consistency of .67 and a test-retest reliability of .86 (Bar-Tal, 1993, 1994).

6. Optimism-Pessimism Instrument

The Optimism-Pessimism Instrument (OPI) is a 56-item questionnaire. Optimism is a disposition representing a bias toward positive aspects of life. Pessimism is a disposition representing a bias toward negative aspects of life. In the OPI, 18 items indicate optimism (O), 18 items

indicate pessimism (P), and 20 items are filler. The scale was developed to measure the degree to which an individual is either an optimist or pessimist in their expectations (Dember et al., 1989).

Respondents are asked to rate their agreement with the items using a four-point Likert-type scale with endpoints of 1 = Strongly Agree and 4 = Strongly Disagree. Unlike other measures of optimism-pessimism such as the Attributional Style Questionnaire (ASQ; Peterson et al., 1982) and the Life Orientation Test (LOT; Scheier & Carver, 1985), OPI measures pessimistic and optimistic tendencies separately.

The OPI has an internal consistency of .84 for optimism and .87 for pessimism. Test-retest reliability are .75 and .84 for optimism and pessimism respectively.

7. Conflict Avoidance (CA)

The Conflict Avoidance (CA) scale is a 23-item self-report measure that assesses a person’s reaction to conflict. High scores on this survey indicate a tendency for wanting to avoid conflicts. The scale is comprised of items from the NEO-PI-R, the Intercultural Adaptation Potential Scale (ICAPS; LeRoux, J. & Matsumoto, D., 2000), the ROAD, and an additional Conflict Avoidance scale taken from (Tjosvold, 1985; Barker, Tjosvold, & Andrews, 1988).

D. PROCEDURE

Data collection was completed in two phases. In the first phase of data collection, eight teams of four NPS

faculty and students were asked to participate in a single 90 minute exercise. Each laboratory exercise took place at the HSIL.

At the beginning of each exercise, participants were asked to register and pick-up a manila folder containing their informed consent form and surveys. After each participant completed their informed consent form, they began completing three of the seven surveys. After completing the surveys, participants were asked to read the C3Fire instructions. Once everyone completed their surveys and had a chance to read over the C3Fire instructions, each of the four team members moved into position on a four person station. Participants played C3Fire as a team training exercise for three minutes. Afterwards, instructions were reviewed and participants were given the opportunity to familiarize themselves with C3Fire. During this 3 minute exercise, questions were encouraged and answered aloud to ensure participants were familiar with the game.

When the training period ended, participants were given another opportunity to ask questions. Then, the first 17 minute data collection session began. At the end of the first seventeen minute session, participants were instructed to finish the remaining four surveys. After each participant answered all surveys, the final 17 minute C3Fire session started.

The first phase of this pilot study consisted of self-organized teams. Results from these teams were used to characterize teams based on individual characteristics and traits and to relate performance to team characteristics.

The second phase of this study used pre-selected teams designed by the researcher. These participants were asked to return for a second 17-minute play of C3Fire. The original self-organized teams were replaced by teams designed on the basis of their individual characteristics. Four teams were constructed on the basis of agreeableness (High vs. Low) and cognitive uncertainty (High vs. Low). The personality trait of agreeableness was measured using the NEO-FFI. Individual responses to CU were collected using the Uncertainty Response Scale (URS). The NEO-FFI classifies individuals into one of five categories (Very Low, Low, Average, High, and Very High) for each personality trait, providing a mechanism for assessing the degree to which a personality trait is present. The URS scores an individual’s degree to which they respond to uncertainty. Using all 32 responses on the URS, summary statistics were calculated. Upper and lower bounds were derived for responses to CU.

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V. RESULTS OF PILOT STUDY

A. SUMMARY STATISTICS OF PERSONALITY TRAITS

The first step of this analysis summarizes individual characteristics and traits from the sample of NPS students and faculty. The sample consisted of thirty-two participants. Responses to the NEO-FFI, the personality measures used in the study, were organized into five-factors with five levels for each factor. Participants were classified as either “Very High” to “Very Low” in each of five personality factors of extroversion, openness, agreeableness, neuroticism, and conscientiousness. Distributions of each personality characteristic are given in Table 2. Across the dimensions of personality, the classification “Average” was the most predominant with thirty-one percent of all responses.

	Extroversion	Openness	Openness	Agreeablenss	Conscientiousness
Very Low	2	2	4	6	4
Low	2	4	7	13	8
Average	14	11	11	8	6
High	10	11	8	4	11
Very High	4	4	2	1	3
Total	32	32	32	32	32

Table 2. Classification of Personality Type and Strength of Classification

Plots similar to Figure 8, are computed for each individual characteristic and trait measure (See Appendix E-F). These plots check for abnormalities in responses to each survey. As Figure 8 demonstrates, responses to each survey were generally varied and none of the responses stand out as anomalous.

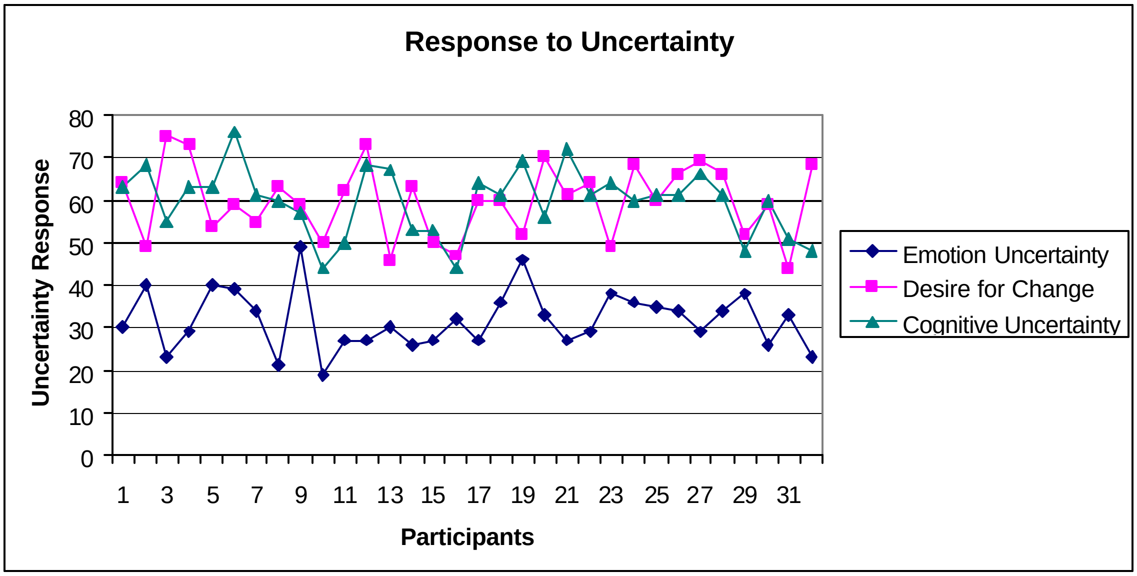


Figure 8. Scores on the Uncertainty Response Scale (URS) by Participant

B. SUMMARY STATISTICS FOR PERFORMANCE

Next we examine team performance. Figure 9 plots the lag time averaged over the number of messages sent in each exercise by team for both trial 1 and trial 2. It illustrates overall performances of seven of the eight teams. One team's performance is omitted because its members had more experience with actual play of the game. Time lag is a performance measure of information exchange and represents currency of information. Smaller time lag represents more current and relevant information. This variable is believed to be critical to team performance in dynamic environments. Having more current information may improve mission effectiveness in network environments. Thus, currency of information is a performance measure for mission effectiveness in NCW (Effective Based Research, 2003) and the performance variable of choice in this study. In both trials, Team 4 had the smallest average time lag

and thus outperformed the other teams with respect to information exchange (Figure 9).

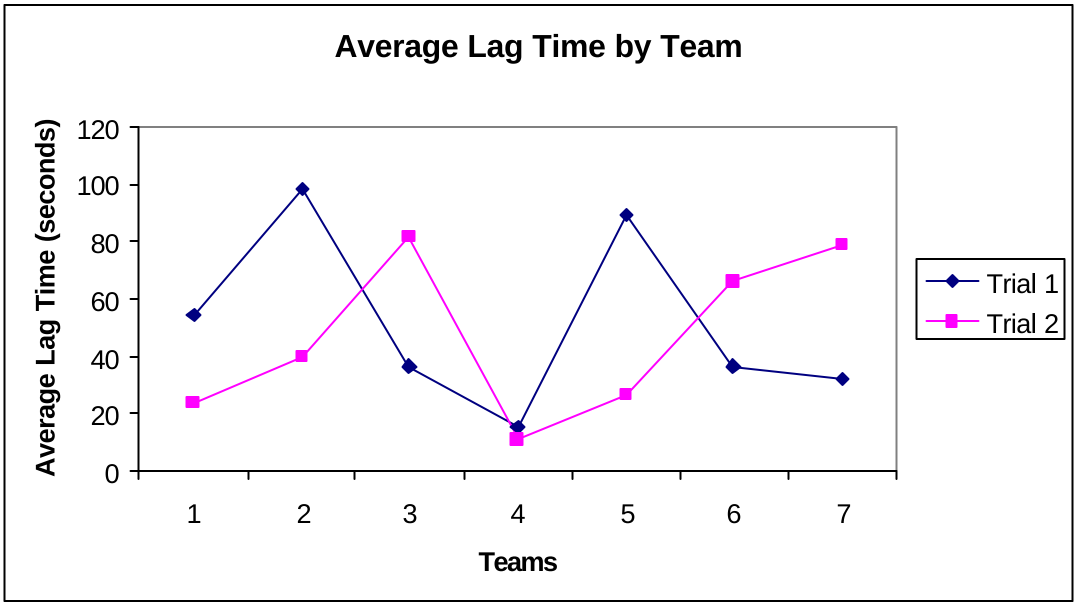


Figure 9. Information Exchange Between by Teams

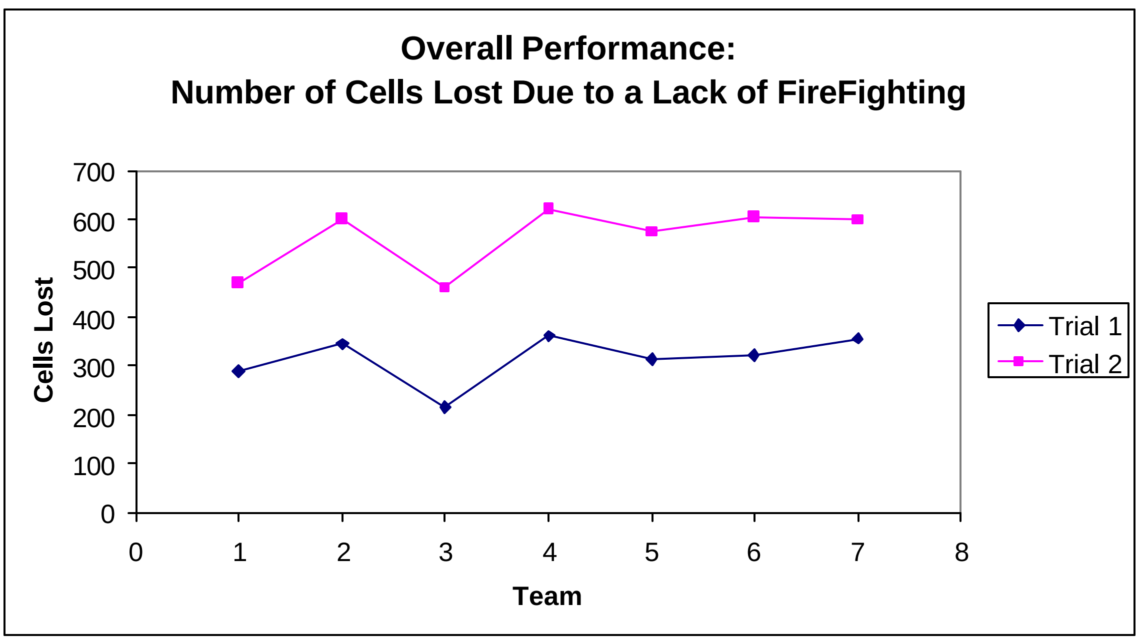


Figure 10. Overall Team Performance, Lost Cells

As Figure 10 illustrates, Team 3 outperformed all other teams in overall performance. Overall performance is

defined as the number of cells lost due to ineffective firefighting.

The analyses and graphs provided in the remaining chapters of this thesis are from trial 1 data only. No comparisons were made between trials due to learning effects and strategy changes within teams. As illustrated in Figures 9 and 10, Team 3's average time lag increased between trials, but overall performance remained relatively superior among teams for both trials 1 and 2. Further analysis from communication logs showed that one member of Team 3 failed to check messages from other teammates until the final minutes of play in trial 2. Thus, Team 3's average time lag increased and forced the remaining three teammates to reorganize quickly to cover for the lack of communication. With Team 3's prior experience in trial 1, they were able to remain effective. Because the experiment was not designed to account for the effects of learning, summary data from trial 2 beyond what has previously been presented is not included.

Individual performance drives team performance. Individual performance within teams may provide insights into variance in team performance. In each exercise, average time lag was recorded for each participant within each team. In C3Fire, a message is hidden and therefore cannot be read until a player clicks the "next button". The assumption here is that when a player "clicks the "next button", the message is read. C3Fire time stamps these events and stores who sends and reads their messages. The time between sending and receiving messages is termed time lag. In a seventeen-minute session, a player can send and

receive a number of messages. It is the responsibility of the player to ensure they remain current on information as it could affect individual and team performance, requiring that players check their mail regularly. For purposes of this study, information is not exchanged until the process of sending and reading a message is completed.

Figure 11 shows individual performance differences in time lag. The box plot shows that team members in Team 4 are less variable in managing information exchanges while members in Teams 2 and 5 are more variable. Following the assumption that individual performance is related to team performance, Team 2 was not expected to have the best performance; it did not.

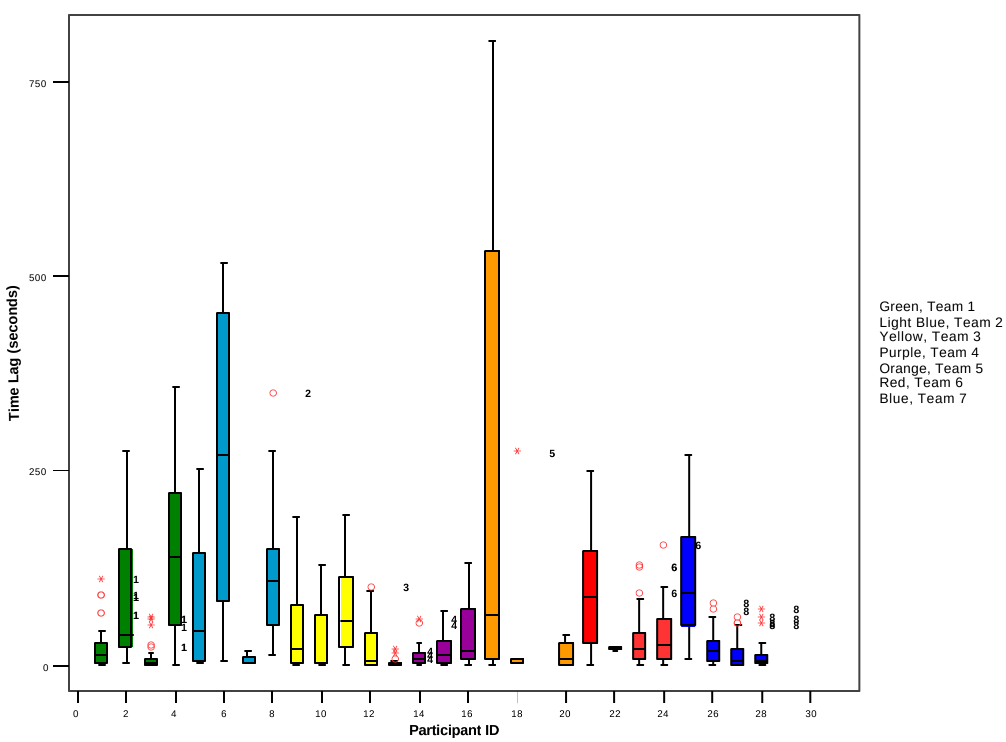


Figure 11. Box plots of Message Time Lags by Participant

Time lag was also measured at the team level. Time lag measured at the team level is postulated to be indicative of team performance. For this study, sensemaking is assumed to be dependent on the currency of information provided and is therefore measured using time lag. Box plots in Figure 12 show differences in time lag at the team level. Team 4 is less variable in managing information whereas Team 2 shows more variability. Following the assumption that team time lag can affect overall team performance, overall performance was expected to be worse for Team 2 than or any other team.

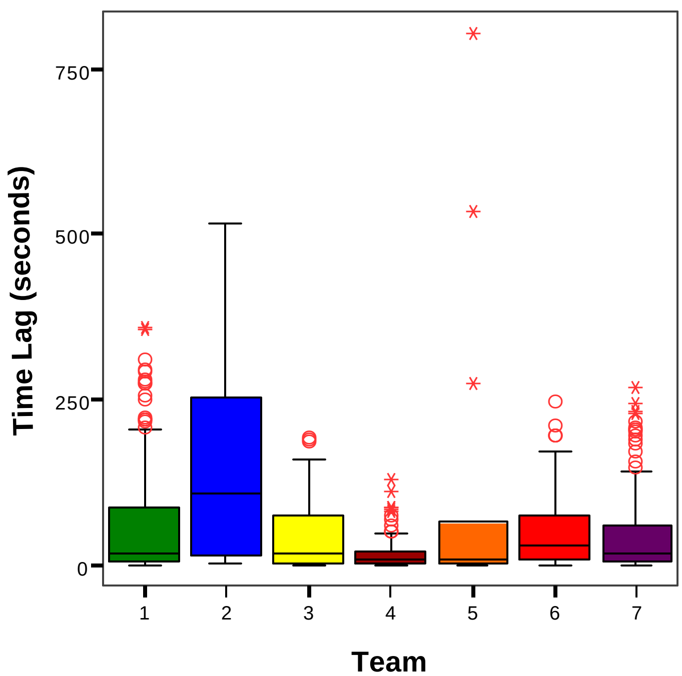


Figure 12. Box plots of Message Time Lag by Team

C. RELATIONSHIPS BETWEEN TEAM PERFORMANCE AND PERSONALITY TRAITS

The degree to which teams consist of members who are similar or dissimilar in individual characteristics and traits may also explain individual and team performance. The scatter plot in Figure 13 compares the degree to which a person is a pessimist against their individual performance (time lag). There appears to be a positive relationship between pessimism scores and time lag. The sample correlation r = .381 with a p-value of .05 for the two-sided test of no correlation. That is to say, less pessimistic individuals (those with lower scores) tend to manage information better than more pessimistic individuals. Additionally, there appears to be a negative relationship (r = -.391, p-value =.043) between individual performance and scores on extroversion, Figure 14.

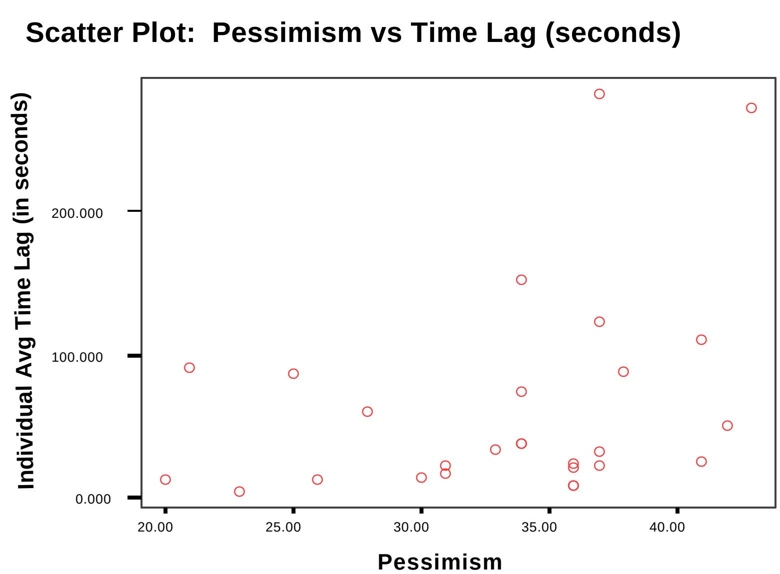


Figure 13. Pessimism vs Average Time Lag for Each Individual

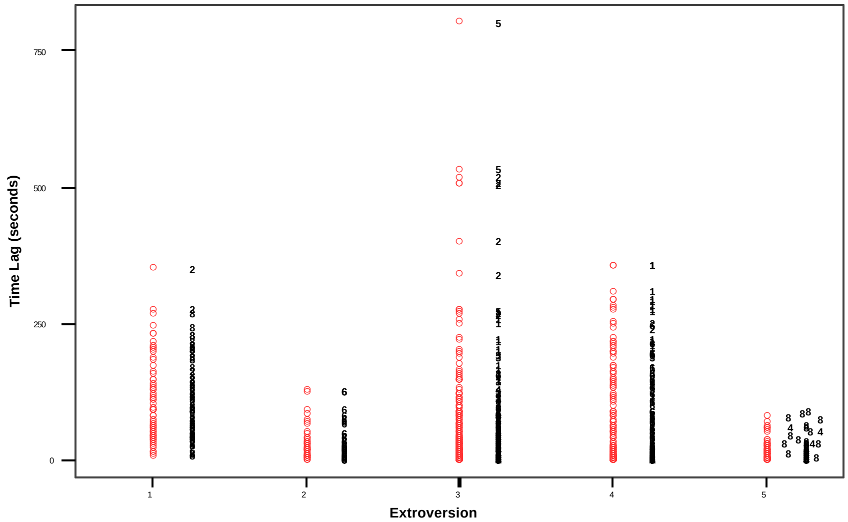


Figure 14. Categories of Extroversion vs Individual Performance

To explore the hypothesis that team member similarity is related to team performance as measured by time lag, standard deviations of characteristics and traits, as measured by the six instruments previously identified, are calculated by teams. Standard deviations provide another technique for characterizing teams based on individual characteristic and traits of its team members. For instance, in the category of neuroticism, a low standard deviation score for a team suggests that the team is similar in regard to neuroticism. Using this technique, it appears that team similarity in optimism is strongly negatively related to average team lag ($r = -.786$, p –value $= .036$) and that team similarity in pessimism is strongly related to the number of lost cells ($r = .821$, p-value $= .036$). These are the only measures of diversity related to the measures of team performance. See Figures 15 and 16 below for the relationships between team similarity in

optimism and pessimism. For additional results on team diverseness, refer to the correlation matrix in Appendix H.

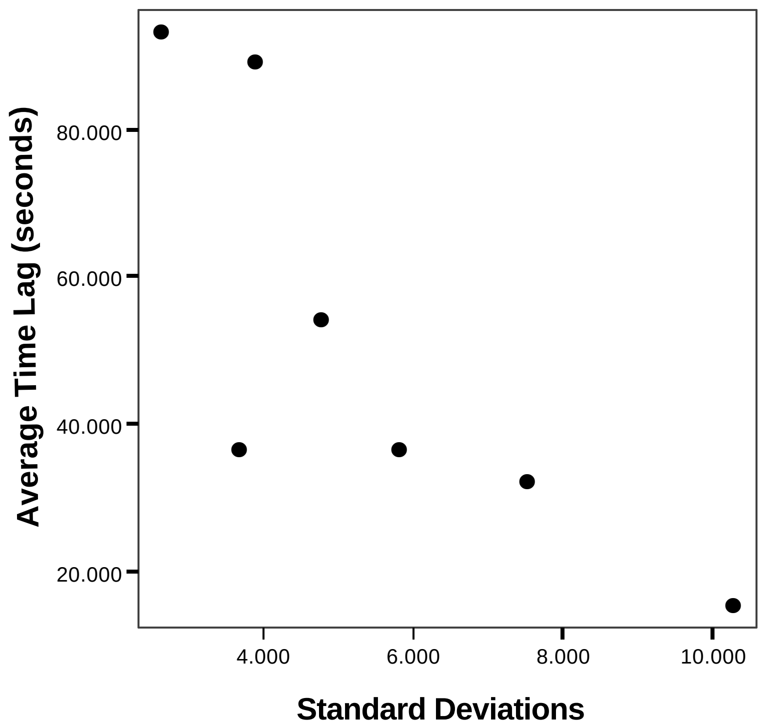


Figure 15. Standard Deviation of Scores on Optimism vs Average Time Lag for each Team

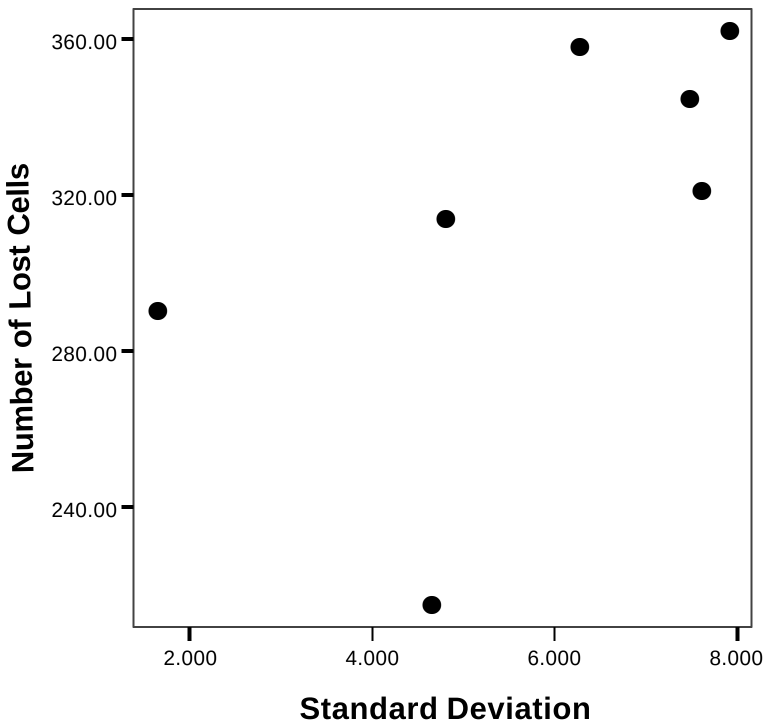


Figure 16. Standard Deviation of Scores on Pessimism vs Number of Lost Cells

A final step in this phase of the data analysis is to determine which individual characteristic and trait measures relate to performance and to each other. A correlation matrix was calculated to determine these relationships (See Appendix G). The individual characteristics and traits that might be related to performance are listed below.

A. Individual Performance:

- Pessimism is positively correlated with individual performance (time lag, $r = .381$, p-value $= .05$)

- Strengths of Extroversion is negatively correlated with individual performance (time lag, r = -.391, p-value = .043)

B. Team Performance:

- Optimism is negatively correlated with team performance (Average Team Lag Time, r= -.786, p-value = .036)
- Pessimism is positively correlated with overall team performance (Number of Lost Cells, r = .821, p-value = .023)

We note that because multiple comparison procedures were not used, these results will need to be tested in future research.

The correlation matrix in Appendix G also provides some insight as to how measures of individual characteristics and traits are related to each other. There is evidence to conclude that each survey measures a separate and distinct individual characteristic and trait.

D. RESULTS FROM PHASE TWO

The results from the second phase of data analyses tests whether performance differs when team member traits are selected by design. Sixteen participants from the original 32 were asked to participate in this phase of the study. Four teams were constructed so that all members on each team had similar agreeableness scores or similar responses to uncertainty scores:

- members of the Team “HA” had high agreeableness;
- members of the Team “LA” had low agreeableness;
- members of the Team “HURS” had a high need to resolve cognitive uncertainty; and

- members of the Team “LURS” had a low need to resolving cognitive uncertainty.

Results for overall performance, as measured by total number of cells lost due to ineffective firefighting, are:

- Team HA = 225 cells vs Team LA = 295 cells
- Team LURS = 3 cells vs Team HURS = 314 cells

With only one team of each type, we can not tell whether the differences in performance reflect actual differences. Thus, Phase Two of this pilot study is for illustrative purposes only.

E. DISCUSSION

There are performance differences for both teams and individuals. For each trial, the average lag time between messages (information exchange) was greater for Team 2 than for any other team. This difference indicates that team decisions were based on old information. Conversely, Team 3 practiced information exchange behaviors that resulted in team decisions based on more current information. Thus, the average lag time between messages was less. On overall performance, Team 3 outperformed all other teams while Team 2 lost the most cells due to fire. See Figures 19 and 20, screen shots from Teams 3 and 2 final performances, respectively.

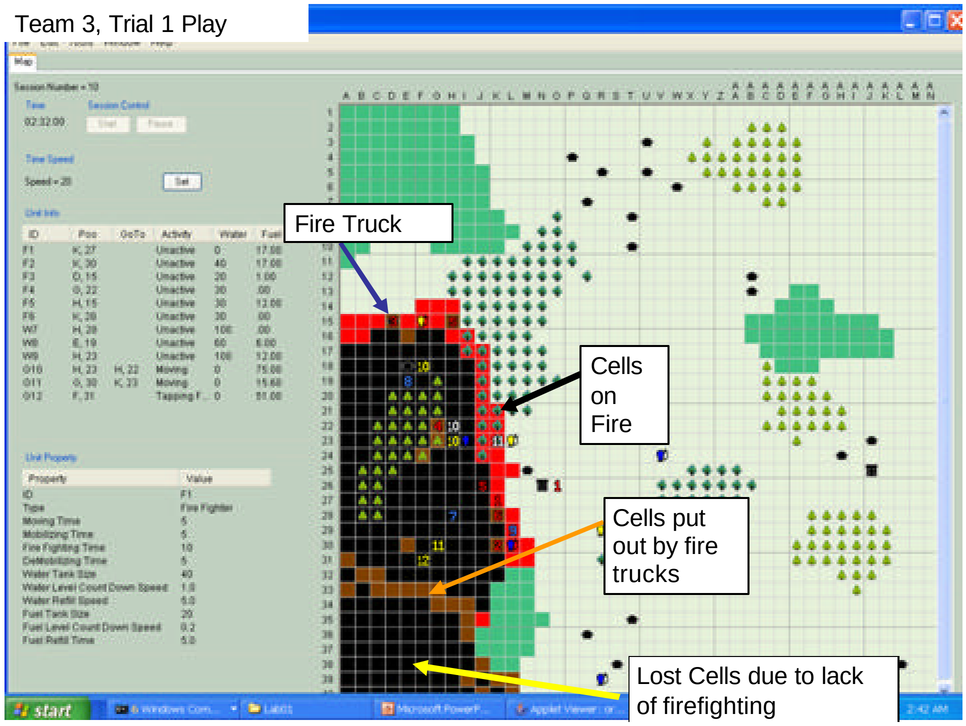


Figure 17. C3Fire Game Screen Shot Team 3, Trial 1

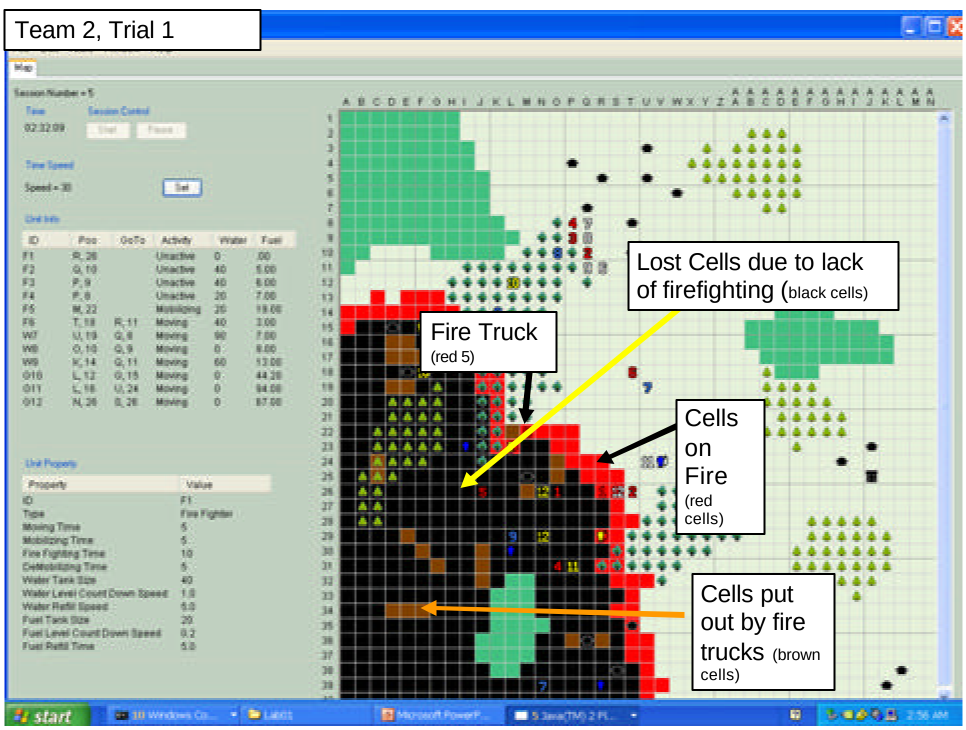


Figure 18. C3Fire Game Screen Shot Team 2, Trial 1

First, to determine if individual and team performance differences were related to individual characteristics and traits, we assumed there would be differences in individual characteristics and traits in the sample. The responses to each survey were generally varied and their distribution unimodal (See Appendix D-F). If survey data were uniform, or characterized by participants desiring to load their responses by answering “Strongly Agree” to every question, the distribution of responses would have shown distinct patterns. Therefore, the assumption that the sample consist of individuals with different characteristics and traits is upheld.

Likewise, we expected that individuals and teams would exchange information at different rates (our measure of performance). As previously discussed, summary plots verified that these differences existed. To better understand these differences, box-plots like the one shown in Figure 12 were created to show how individual performance from each participant relates to their team member performance. Differences in variability exist as reflected in the box-plot of participant six and 17 in Figure 12. Generally, when comparing performances among teams, teams composed of members who were less consistent in checking messages (information management) performed worse than teams composed of members who were more consistent. Information management behaviors in Team 3 were more consistent and outperformed the other teams in both measures of performance: information currency and number of cells lost.

Individual characteristics and traits were correlated with individual performances to determine if relationships exist. From Appendix G, only two personality traits pessimism and extroversion appear to be related to individual performance. The positive relationship between pessimism and individual performance coincides with the literature suggesting that feelings of wanting to give-up and surrender are related to poor performance. In the game, as the fire became more out of controlled and less manageable, these individuals would be expected to withdraw from the game and refuse inputs from their teammates. Likewise, the negative relationship between the degrees of extroversion (1 = Very Low to 5 = Very High) and individual performance also agree with the literature. Extroverts are said to help facilitate intra-team communication and are generally ready to share information (Bradley & Herbert, 1997). Thus, their individual time lag can be expected to decrease (i.e., their performance improves) as a result of being more extroverted.

Also, the correlation matrix in Appendix H is color-coded to reflect which individual characteristics and traits were related to one another. The cells highlighted in red indicate a p-value < .01 for testing the null hypothesis of correlation.

The second correlation matrix (See Appendix H) suggests that diverse teams perform differently from homogenous teams on two of six individual characteristic and trait variables, pessimism and optimism. Time lag improves the more similar team members are on their measure of optimism ($r = -.786$, p-value = .036). These teams

exhibit quicker information exchanges resulting in more current information (See Figure 15). Conversely, performance degrades the more similar team members are in their reports of pessimism. This finding coincides with the belief that negativity breeds negativity.

Results from phase two of the analysis address the third question as to whether there are performance differences when blocking on various team member traits in team design. Cognitive uncertainty (CU) and the personality trait agreeableness are the two individual characteristics and traits identified for this phase of the analysis. Attrition, a very small sample size to start, and the fact that one team chose not to use any communication technology within their session, prevents any statistical analysis beyond graphs to summarize the data. Figure 22 shows that teams consisting of highly agreeable members have lower information management times than teams of low agreeable members. This finding is consistent with what the literature informs us about agreeableness and information exchange. Teams characterized by agreeable members are expected to exhibit interpersonal skills such as the ability to resolve conflict and communicate openly in a manner which promotes information exchange and sensemaking (Aronoff & Wilson, 1985; Neuman & Wright, 1999). Thus, the time lag between a message being sent and read is expected to be lower for a team composed of non agreeable members. Average team time lag for the High Agreeable team was 26.4 seconds with a standard deviation of 25.9 where as the Low Agreeable team had an average time lag of 67.9 seconds with a standard deviation of 56.7 seconds.

VI. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

Advocates of NCW claim that it will improve information sharing by “…robustly networking a force”, thereby improving mission effectiveness. However, this claim has not been tested or validated. The literature is inconclusive in identifying individual characteristics and traits that would affect macrocognitive processes such as information sharing and sensemaking.

To guide the analysis about NCW, the model of DMSC was applied and adapted. This model provided a conceptual framework for describing macrocognitive processes such as information exchange and sensemaking. Feedback loops and lenses presented in the model illustrate how information can be omitted or included in individual or team cognition. The lenses function as filters which help characterize differences in individual characteristics and traits. The feedback loops in the DMSC are representative of time lag among individuals on the teams and time lag affects on individual and overall performance.

Human factors engineering (HFE) is a discipline that focuses on designing systems around users (i.e., user-centered design) and employing technology that acknowledges and complements human characteristics and traits. Although the pilot study, by its very nature, did not produce significant results for assessing performance differences, it is evident that performance differences can be explained by individual characteristics and traits. There are tremendous variations in the behaviors, expectations, and

mental capabilities of people. As the DMSC model depicts, individual characteristics and traits such as personality, cultural adaptability, optimism–pessimism, and responses to uncertainty occlude interactions within teams and technology. These differences, if unaccounted for in team design, training, or systems design, are barriers that obstruct both individual and team performance.

Failure in understanding individual characteristic and trait differences within the DoD population creates disconnects between networking technologies and the capabilities of the men and women expected to operate within a network centric system. The personnel and training domains focus on identifying these disconnects by focusing on the target audience. The target audience includes the types of systems used (i.e., communications technologies and group decision support systems) and key statistics on the personnel pool. Assessing users on the basis of personality, cultural adaptability, and optimism-pessimism is a first step in achieving perceived advantages of distributed teamwork. Testing a variety of team compositions of military personnel will provide insight as to the types of people that are better suited for distributed teamwork. The pilot study suggests that extroverts and optimists are more likely to engage in information exchanges via networks.

B. RECOMMENDATIONS

Empirical evidence must be provided to facilitate the acceptance of NCW as an emerging theory of warfare. Basic and applied research must be carefully conducted to begin identifying and isolating individual characteristic and

trait variables which may jeopardize mission effectiveness in the Information Age. Technology solutions developed independent of understanding human behaviors, such as macrocognition in teams, invite failure.

C. FOLLOW-ON RESEARCH

People and their interaction with technology are the primary and secondary focuses of NCW. To totally integrate systems, additional research must apply process models of human technology interaction such as the DMSC to experimental, field, or observational settings designed to test facets of NCW. These kinds of dynamic models provide extreme possibilities in advancing our understanding of which human factors have the greatest affect on performance.

The C3Fire simulation uses asynchronous technology (i.e., e-mail) for coordination and communication within teams. Little is known about how the types of technologies, asynchronous or synchronous, influence the quality of macrocognitive processing at the individual or team level. Our understanding about e-mail, text-chat, video teleconferencing, or face-to-face communication systems will affect the quality of team interactions (i.e., communication, planning, and coordination) and must guide the development and deployment of NCW technologies. Future research should include an examination of individual characteristics and traits in order to further understand which types of personnel are more comfortable with employing asynchronous technologies in macrocognitive processes. The literature suggests that people who have high needs to achieve certainty may gather and hoard

information before contributing or making a decision. This behavior would undermine NCW claims of networking a distributed force to improve the quality and amount of information sharing to achieve mission effectiveness. Moreover, HFE research should focus on varying communication modalities and technologies to determine which communication modalities enhance information exchange and sensemaking, making them better at facilitating distributed teamwork.

Research about human performance has traditionally used civilian undergraduate students. However, military transformation implies understanding the current population of users, and redeveloping tactics, techniques, and procedures that better enable them to achieve mission effectiveness. Critical information in determining military personnel requirements needs to be gathered. Therefore, human performance researchers must redefine their target populations and exploit service men and women at various military schools.

The first tenet of NCW postulates that if a force is robustly networked, then they would share information and that this information exchange would lead to improve mission effectiveness. There are other human factors such as organizational structure, cross planning and execution between military versus non-military organizations, trust, and team cohesion, which affect team performance. Objective and qualitative measures of individual and team performance in a network environment need to be established. The results of individual and team measures could then be used to maximize human-system performance.

APPENDIX A. GLOSSARY AND ACRONYMS

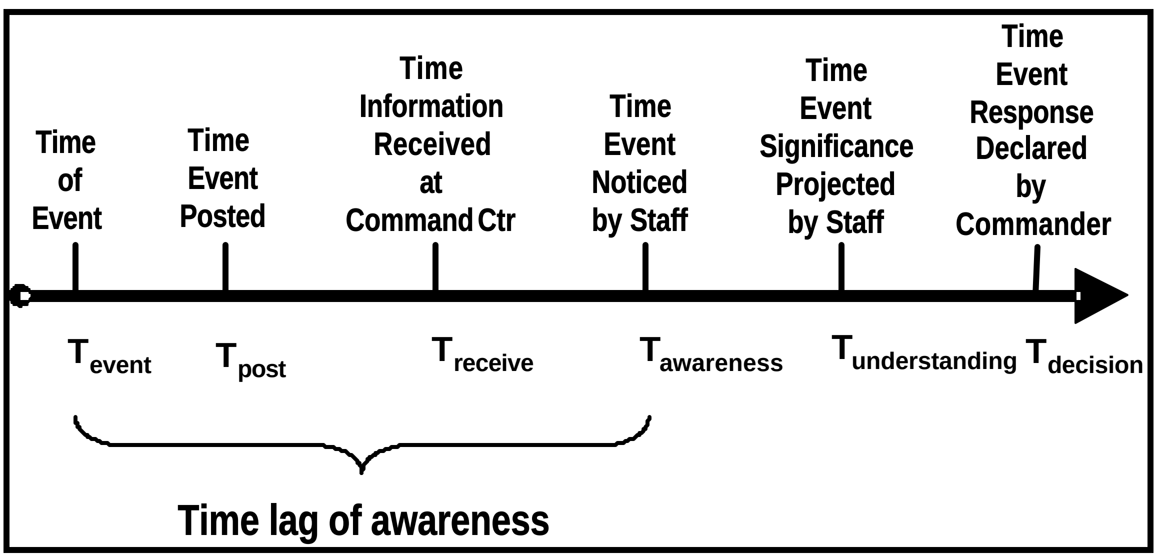
AACS	Ability to Achieve Cognitive Structure, the extent to which an individual is able to avoid information that either cannot be categorized or clashes with their existing knowledge and/or ability to organize their knowledge to fit an already existing cognitive structure (Bar-Tal, 1994, p. 46)
AWACS-AEDGE	Airborne Warning and Control System – Agent Enabled Decision Guide Environment
CA	Conflict Avoidance
C2	Command and Control
DMSC	Dynamic Model of Situated Cognition
HSI	Human Systems Integration
HSIL	Human Systems Integration Laboratory
NCS	Need for Cognitive Structure, the desire for clear and firm knowledge concerning a given topic as opposed to ambiguity doubt, or confusion (Kruglanski, 1989, as cited in Bar-Tal, 1994, p. 46)
NCW	Network Centric Warfare, the conduct of military operations using networked information systems to generate a flexible and agile military force that acts under a common commander’s intent, independent of the geographic or organizational disposition of the individual elements, and in which the focus of the warfighter is broadened away from individual, unit or platform concerns to give primacy to the mission and responsibilities of the team, task group or coalition. (Fewell & Hazen, 2003, p. 39)
NEO-FFI	NEO – Five-Factor Inventory

OPI	Optimism – Pessimism Instrument
Optimism	A disposition inclining one to positive expectations
Pessimism	A disposition inclining one to negative expectations
SABRE	Situation Authorable Behavior Research Environment
Sensemaking	A behavior that is both internal (i.e., cognitive) and external (i.e. procedural), which allows the individual to construct and design their movement through time-space (Dervin, 1983, p.3)
URS	Uncertainty Response Scale
Virtual Team	a collection of individuals who are interdependent in their tasks, who share responsibility for outcomes, who see themselves and who are seen by others as an intact social entity embedded in one or more larger social systems, and who manage their relationship across organizational boundaries. (Powell, Piccoli, and Ives ,2004, p. 241)

APPENDIX B. NCW DEPENDENT VARIABLE

A. INFORMATION EXCHANGE (CURRENCY, FROM EVIDENCED BASED RESEARCH, 2004, P.37)

Attribute	Metrics
Objective Measures	Measures quality in reference to criteria that are independent of the situation
Correctness	Correspondence with ground truth-correlation coefficient (0= no convergence, 1=full convergence between individual's awareness and ground truth)
Consistency	Degree of 'deviation' from awareness gained from previous time period
Currency	Time lag of awareness
Precision	Level of granularity of awareness
Fitness for Use Measures	Measures quality in reference to criteria that are determined by the situation
Completeness	Percentage of ground truth picture included in awareness
Accuracy	Degree to which precision matches what is needed (0=no match, 10=high degree of matching between precision level needed and available)
Relevance	Proportion of awareness that is related to task at hand
Timeliness	Degree to which currency matches what is needed (0=no match, 10=high degree of matching between currency level needed and available)
Uncertainty	Confidence level (0% =uncertain, 100%= certain) or confidence interval (95%, 90%, etc.) of awareness



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APPENDIX C. POINTS OF CONTACT

A. NAVAL POSTGRADUATE SCHOOL

Nita Lewis Miller, Ph.D.
Director, Human Systems Integration Program

Lyn R. Whitaker, Ph.D.
Associate Professor of Operations Research

Lawrence G. Shattuck, Ph.D.
Co-Director, Human Systems Integration Program
Senior Lecturer

B. C3FIRE

Rego Granlund, Ph.D.
Developer of C3Fire
Professor, Linköping Institute of Technology

Kip Smith, Ph.D.
Professor, Linköping Institute of Technology

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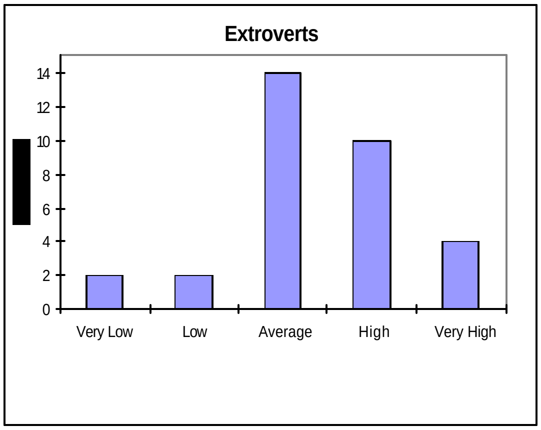
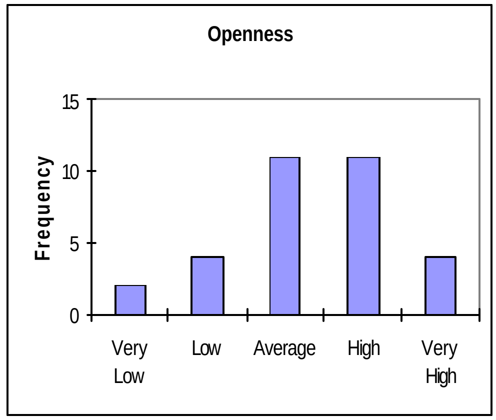
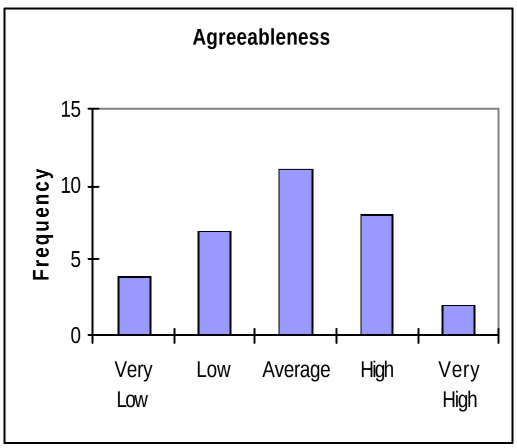
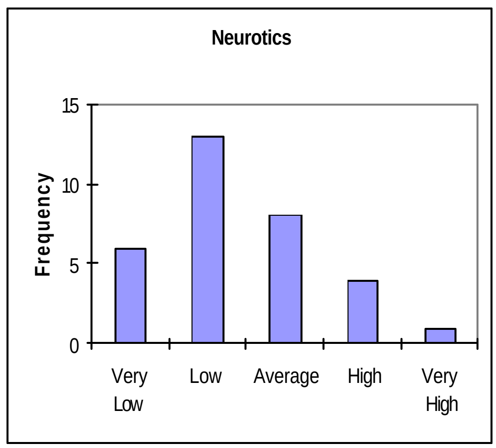
APPENDIX D. SURVEY RESULTS

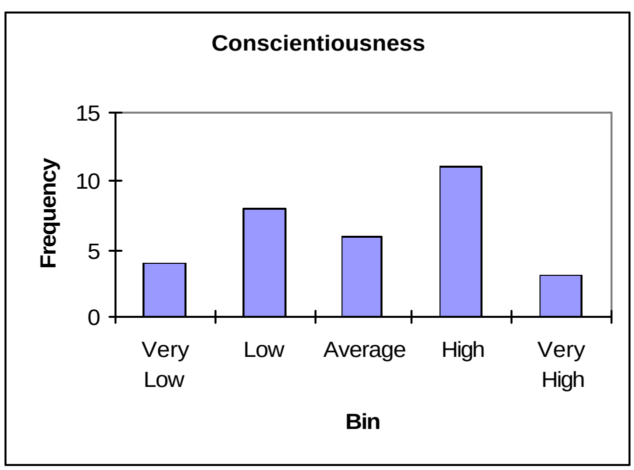
Personality results measured using the NEO-FFI











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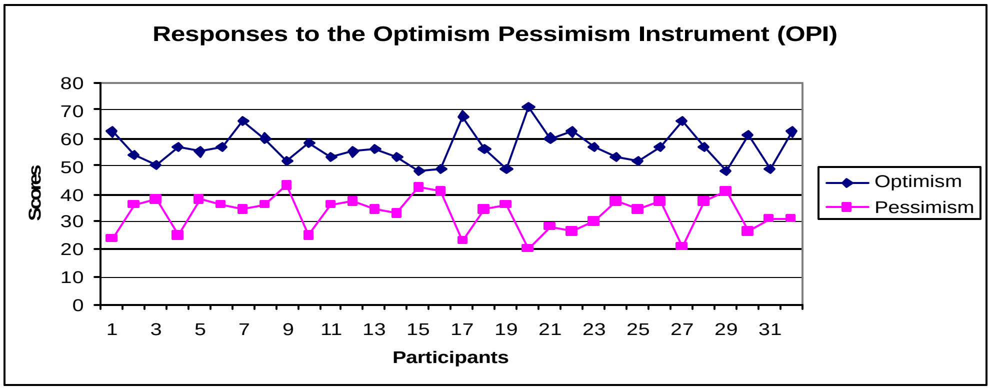
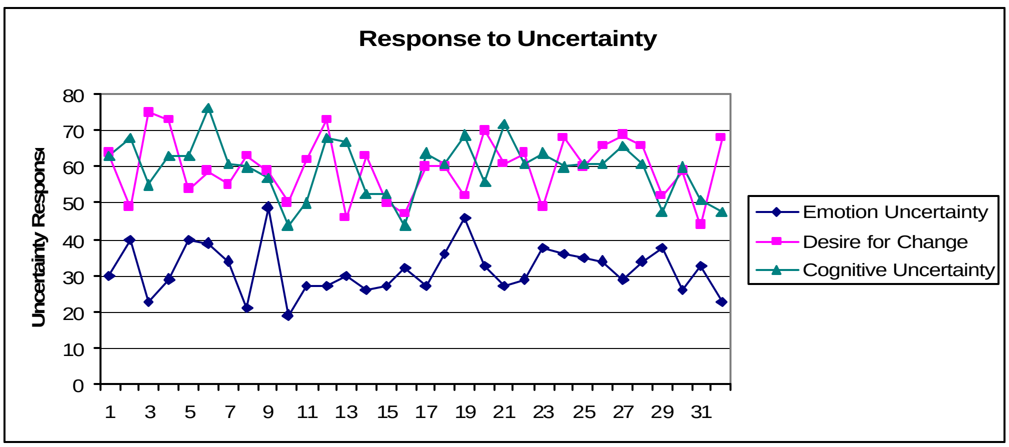
APPENDIX E. SURVEY RESULTS

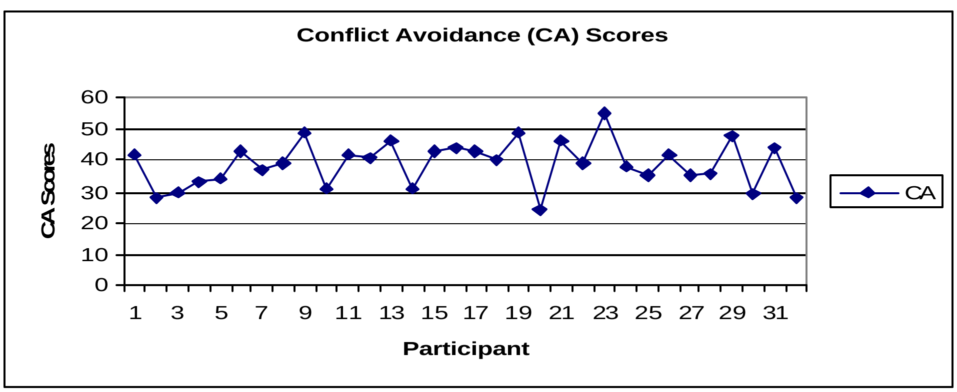
Optimism and Pessimism results using the OPI.



Responses to Uncertainty using the URS



Conflict Avoidance Responses



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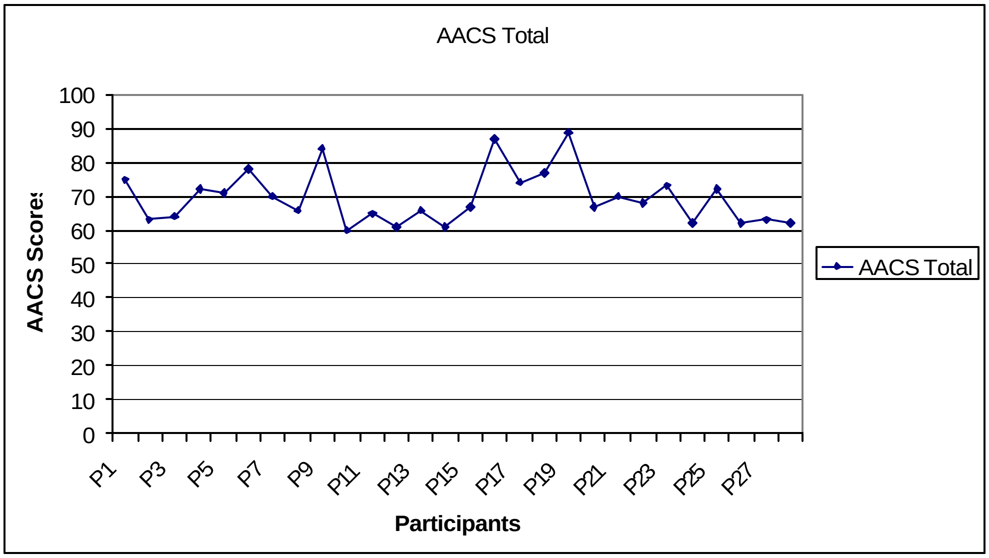
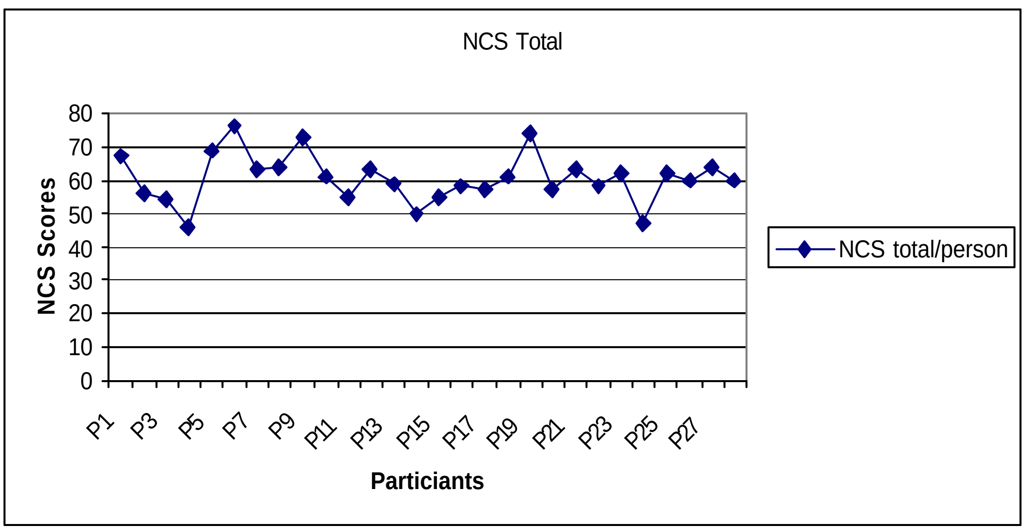
APPENDIX F. SURVEY RESULTS

Ability to Achieve Cognitive Structure Responses



Need for Cognitive Structure Responses



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APPENDIX G. CORRELATION MATRIX OF INDIVIDUAL CHARACTERISTICS AND TRAITS WITH TEAM PERFORMANCE

			Individual Avg Time Lag (in seconds)	Individual Std of Time Lag (ins seconds)	Emotion Uncertainty	Desire For Change	Cognitive Uncertainty	Need for cognitive structure	Ability to acheive cognitive structure	Optimisim	Pessimism	Extroversion (score)	Opennesses (score)	Agreeableness (score)	Neuroticism (score)	Conscientious-ness (score)	Extroversion (Category)	Openness (Category)	Agreeableness (Category)	Neuroticism (Category)	Conscientious-ness (Category)	Conflict Avoidance (score)
Spearman's rho	Individual Avg Time Lag (in seconds)	Correlation Coefficient	1.000	0.943	0.171	-0.007	-0.139	0.159	-0.281	-0.232	0.381	-0.261	0.074	-0.252	0.307	-0.039	-0.391	0.089	-0.273	0.342	-0.112	0.002
		Sig. (2-tailed)	.	0.000	0.395	0.971	0.490	0.429	0.156	0.245	0.050	0.189	0.713	0.205	0.119	0.848	0.043	0.660	0.169	0.081	0.578	0.990
		N	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27
	Individual Std of Time Lag (ins seconds)	Correlation Coefficient		1.000	0.099	-0.073	-0.126	0.162	-0.185	-0.218	0.275	-0.137	-0.055	-0.259	0.196	0.037	-0.272	-0.042	-0.288	0.219	-0.021	0.020
		Sig. (2-tailed)		.	0.624	0.716	0.531	0.420	0.355	0.276	0.165	0.495	0.785	0.192	0.328	0.853	0.170	0.835	0.145	0.272	0.916	0.922
		N		27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27
	Emotion Uncertainty	Correlation Coefficient			1.000	-0.237	0.356	0.381	0.561	-0.378	0.430	-0.319	-0.033	0.136	0.600	-0.023	-0.366	-0.094	0.035	0.649	-0.151	0.404
		Sig. (2-tailed)			.	0.235	0.068	0.050	0.002	0.052	0.025	0.105	0.872	0.499	0.001	0.911	0.060	0.639	0.862	0.000	0.452	0.037
		N			27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27
	Desire For Change	Correlation Coefficient				1.000	0.016	-0.040	-0.508	0.506	-0.156	0.161	0.587	0.222	-0.260	0.323	0.133	0.521	0.246	-0.233	0.276	-0.520
		Sig. (2-tailed)				.	0.936	0.844	0.007	0.007	0.438	0.421	0.001	0.267	0.190	0.101	0.510	0.005	0.217	0.242	0.163	0.005
		N				27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27
	Cognitive Uncertainty	Correlation Coefficient					1.000	0.182	0.337	0.304	-0.249	0.087	-0.217	0.493	-0.104	0.502	0.004	-0.261	0.352	-0.050	0.431	0.260
		Sig. (2-tailed)					.	0.365	0.085	0.124	0.211	0.665	0.277	0.009	0.606	0.008	0.986	0.188	0.071	0.805	0.025	0.189
		N					27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27
	Need for cognitive structure	Correlation Coefficient						1.000	0.154	-0.054	0.357	-0.184	-0.255	-0.141	0.286	0.057	-0.182	-0.203	-0.193	0.275	-0.128	0.156
		Sig. (2-tailed)						.	0.444	0.789	0.068	0.359	0.198	0.484	0.148	0.777	0.364	0.309	0.334	0.165	0.525	0.436
		N						27	27	27	27	27	27	27	27	27	27	27	27	27	27	27
	Ability to acheive cognitive structure	Correlation Coefficient							1.000	-0.205	0.098	0.056	-0.457	0.238	0.300	0.048	0.099	-0.496	0.170	0.271	0.063	0.503
		Sig. (2-tailed)							.	0.306	0.628	0.780	0.017	0.232	0.128	0.810	0.622	0.008	0.398	0.172	0.753	0.008
		N							27	27	27	27	27	27	27	27	27	27	27	27	27	27
	Optimisim	Correlation Coefficient								1.000	-0.698	0.475	0.130	0.408	-0.667	0.420	0.529	0.111	0.380	-0.688	0.480	-0.482
		Sig. (2-tailed)								.	0.000	0.012	0.518	0.035	0.000	0.029	0.005	0.580	0.051	0.000	0.011	0.011
		N								27	27	27	27	27	27	27	27	27	27	27	27	27
	Pessimism	Correlation Coefficient									1.000	-0.517	0.068	-0.302	0.727	-0.270	-0.563	0.133	-0.245	0.783	-0.406	0.372
		Sig. (2-tailed)									.	0.006	0.735	0.126	0.000	0.174	0.002	0.509	0.218	0.000	0.035	0.056
		N									27	27	27	27	27	27	27	27	27	27	27	27
	Extroversion (score)	Correlation Coefficient										1.000	0.027	0.343	-0.622	0.342	0.889	-0.085	0.369	-0.596	0.390	-0.265
		Sig. (2-tailed)										.	0.893	0.080	0.001	0.081	0.000	0.672	0.058	0.001	0.045	0.182
		N										27	27	27	27	27	27	27	27	27	27	27
	Opennesses (score)	Correlation Coefficient											1.000	0.118	-0.100	-0.041	0.012	0.949	0.191	0.058	-0.108	-0.428
		Sig. (2-tailed)											.	0.558	0.619	0.839	0.953	0.000	0.341	0.775	0.590	0.026
		N											27	27	27	27	27	27	27	27	27	27
	Agreeableness (score)	Correlation Coefficient												1.000	-0.262	0.345	0.204	0.018	0.959	-0.156	0.353	0.166
		Sig. (2-tailed)												.	0.187	0.078	0.308	0.931	0.000	0.437	0.071	0.409
		N												27	27	27	27	27	27	27	27	27
	Neuroticism(score)	Correlation Coefficient													1.000	-0.438	-0.638	-0.020	-0.268	0.923	-0.477	0.433
		Sig. (2-tailed)													.	0.022	0.000	0.921	0.177	0.000	0.012	0.024
		N													27	27	27	27	27	27	27	27
	Conscientious-ness (score)	Correlation Coefficient														1.000	0.228	-0.073	0.281	-0.383	0.953	-0.140
		Sig. (2-tailed)														.	0.253	0.717	0.155	0.048	0.000	0.485
		N														27	27	27	27	27	27	27
	Extroversion (Category)	Correlation Coefficient															1.000	-0.054	0.273	-0.672	0.301	-0.393
		Sig. (2-tailed)															.	0.788	0.172	0.000	0.128	0.043
		N															27	27	27	27	27	27
	Openness (Category)	Correlation Coefficient																1.000	0.115	0.107	-0.126	-0.458
		Sig. (2-tailed)																.	0.569	0.596	0.530	0.016
		N																27	27	27	27	27
	Agreeableness(Category)	Correlation Coefficient																	1.000	-0.186	0.322	0.086
		Sig. (2-tailed)																	.	0.352	0.102	0.671
		N																	27	27	27	27
	Neuroticism (Category)	Correlation Coefficient																		1.000	-0.481	0.481
		Sig. (2-tailed)																		.	0.011	0.011
		N																		27	27	27
	Conscientious-ness(Category)	Correlation Coefficient																			1.000	-0.186
		Sig. (2-tailed)																			.	0.353
		N																			27	27
	Conflict Avoidance (score)	Correlation Coefficient																				1.000
		Sig. (2-tailed)																				.
		N																				27

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APPENDIX H. CORRELATION MATRIX OF TEAM CHARACTERISTICS (DEGREE OF SIMILARITY) WITH PERFORMANCE

			Team_Average_ Time Lag (in sec)	Optimisim(similiarity)	Pessimism (similarity)	Extroversio n(similarity)	Openness(similarity)	Agreeable(similarity)	Neuroticism (similarity)	Conscientiousness (similarity)	Emotion Uncertainty(similarity)	Desire_for _Change(similarity)	Cognitive_ Uncertainty (similarity)	Conflict Avoidance (similarity)	Number of Lost Cells
Spearman's rho	Team_Average_Time Lag (in sec)	Correlation Coefficient	1.000	-0.786	-0.321	-0.179	-0.750	-0.429	-0.393	-0.286	0.286	0.107	0.250	-0.429	-0.393
		Sig. (2-tailed)	.	0.036	0.482	0.702	0.052	0.337	0.383	0.535	0.535	0.819	0.589	0.337	0.383
		N	7	7	7	7	7	7	7	7	7	7	7	7	7
	Optimisim (similiarity)	Correlation Coefficient	-0.786	1.000	0.464	0.107	0.464	0.750	0.536	0.500	-0.143	-0.250	-0.607	0.393	0.607
		Sig. (2-tailed)	0.036	.	0.294	0.819	0.294	0.052	0.215	0.253	0.760	0.589	0.148	0.383	0.148
		N	7	7	7	7	7	7	7	7	7	7	7	7	7
	Pessimism (similarity)	Correlation Coefficient	-0.321	0.464	1.000	0.607	0.071	0.036	0.857	0.536	-0.036	-0.071	-0.393	0.357	0.821
		Sig. (2-tailed)	0.482	0.294	.	0.148	0.879	0.939	0.014	0.215	0.939	0.879	0.383	0.432	0.023
		N	7	7	7	7	7	7	7	7	7	7	7	7	7
	Extroversion(similarity)	Correlation Coefficient	-0.179	0.107	0.607	1.000	0.321	-0.286	0.679	0.286	0.393	0.429	0.357	0.321	0.714
		Sig. (2-tailed)	0.702	0.819	0.148	.	0.482	0.535	0.094	0.535	0.383	0.337	0.432	0.482	0.071
		N	7	7	7	7	7	7	7	7	7	7	7	7	7
	Openness (similarity)	Correlation Coefficient	-0.750	0.464	0.071	0.321	1.000	0.214	0.214	-0.107	0.321	0.286	0.321	0.679	0.393
		Sig. (2-tailed)	0.052	0.294	0.879	0.482	.	0.645	0.645	0.819	0.482	0.535	0.482	0.094	0.383
		N	7	7	7	7	7	7	7	7	7	7	7	7	7
	Agreeable (similarity)	Correlation Coefficient	-0.429	0.750	0.036	-0.286	0.214	1.000	0.321	-0.036	0.036	-0.643	-0.464	-0.071	0.143
		Sig. (2-tailed)	0.337	0.052	0.939	0.535	0.645	.	0.482	0.939	0.939	0.119	0.294	0.879	0.760
		N	7	7	7	7	7	7	7	7	7	7	7	7	7
	Neuroticism (similarity)	Correlation Coefficient	-0.393	0.536	0.857	0.679	0.214	0.321	1.000	0.250	0.179	-0.286	-0.179	0.143	0.750
		Sig. (2-tailed)	0.383	0.215	0.014	0.094	0.645	0.482	.	0.589	0.702	0.535	0.702	0.760	0.052
		N	7	7	7	7	7	7	7	7	7	7	7	7	7
	Conscientiousness (similarity)	Correlation Coefficient	-0.286	0.500	0.536	0.286	-0.107	-0.036	0.250	1.000	-0.429	0.286	-0.643	0.321	0.571
		Sig. (2-tailed)	0.535	0.253	0.215	0.535	0.819	0.939	0.589	.	0.337	0.535	0.119	0.482	0.180
		N	7	7	7	7	7	7	7	7	7	7	7	7	7
	Emotion Uncertainty (similarity)	Correlation Coefficient	0.286	-0.143	-0.036	0.393	0.321	0.036	0.179	-0.429	1.000	0.321	0.607	0.321	0.321
		Sig. (2-tailed)	0.535	0.760	0.939	0.383	0.482	0.939	0.702	0.337	.	0.482	0.148	0.482	0.482
		N	7	7	7	7	7	7	7	7	7	7	7	7	7
	Desire_for_Change (similarity)	Correlation Coefficient	0.107	-0.250	-0.071	0.429	0.286	-0.643	-0.286	0.286	0.321	1.000	0.429	0.607	0.286
		Sig. (2-tailed)	0.819	0.589	0.879	0.337	0.535	0.119	0.535	0.535	0.482	.	0.337	0.148	0.535
		N	7	7	7	7	7	7	7	7	7	7	7	7	7
	Cognitive_Uncertainty (similarity)	Correlation Coefficient	0.250	-0.607	-0.393	0.357	0.321	-0.464	-0.179	-0.643	0.607	0.429	1.000	0.000	-0.214
		Sig. (2-tailed)	0.589	0.148	0.383	0.432	0.482	0.294	0.702	0.119	0.148	0.337	.	1.000	0.645
		N	7	7	7	7	7	7	7	7	7	7	7	7	7
	Conflict Avoidance (similarity)	Correlation Coefficient	-0.429	0.393	0.357	0.321	0.679	-0.071	0.143	0.321	0.321	0.607	0.000	1.000	0.679
		Sig. (2-tailed)	0.337	0.383	0.432	0.482	0.094	0.879	0.760	0.482	0.482	0.148	1.000	.	0.094
		N	7	7	7	7	7	7	7	7	7	7	7	7	7
	Number of Lost Cells	Correlation Coefficient	-0.393	0.607	0.821	0.714	0.393	0.143	0.750	0.571	0.321	0.286	-0.214	0.679	1.000
		Sig. (2-tailed)	0.383	0.148	0.023	0.071	0.383	0.760	0.052	0.180	0.482	0.535	0.645	0.094	.
		N	7	7	7	7	7	7	7	7	7	7	7	7	7

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